

Supplementary Materials for Feature Distributions of Technologies

Supplementary Contents: Information about Candidate Technologies

Table I. All the 470 candidate technologies along with their origins and contents, corresponding keywords that were obtained through comparison of search query volumes of the candidate keywords derived from the root keyword and a co-occurrence analysis for multiple keywords, and technologies included or excluded in the analysis of distribution and evolution. It should be noted that most of the technological contents are presented in their original languages, i.e., English, Russian and Chinese.

No.	Content	Keyword	Included
Government: United States of America			
Plan 1: National Robotics Initiative			
1	Autonomy: principles, computational methods, and architectures for enhancing intelligent perception and decision making by single agents and teams of agents in unstructured environments; examples include human interaction with unmanned systems for supervision, collaborative control, and peer-to-peer collaboration.	perception and decision making	Y
2	Social, Behavioral, and Economic: research to understand long-term social, behavioral, and economic implications of co-robots across all areas of human activity, including uptake, diffusion, and use among different demographic and social groups, including appropriate incentives and potential disparities and ethical implications; workforce participation among various diverse groups, including the elderly and non-native English speakers.	co-robots	Y
3	Sensing and Perception: sensor/biosensor systems and networks	biosensor	Y
4	Sensing and Perception: object perception in clutter and various lighting conditions	object perception	Y
5	Sensing and Perception: sensors capable of discriminative monitoring of multiple agents like chemical and biological threat agents, biomarkers and metabolites, and plant pathogens	discriminative	Y
6	Sensing and Perception: enhanced immersive interfaces using multi-model displays	multi-model displays	Y
7	Sensing and Perception: real-time estimation of human physical and emotional state	estimation	Y
8	Sensing and Perception: real-time prediction of human intent	prediction	Y
9	Sensing and Perception: methods for object recognition and human activity monitoring	recognition monitoring	Y
10	Modeling and Analysis: models of physical human–robot interactions for collaborative tasks	interactions for collaborative	Y

No.	Content	Keyword	Included
	(e.g., assembly) and associated performance metrics; verifiable simulation models and benchmarking	tasks	
11	Modeling and Analysis: verifiable simulation models and benchmarking	simulation benchmarking	Y
12	Modeling and Analysis: engineering and human factor models of dynamic interactive human–robot teams	engineering human factors	Y
13	Modeling and Analysis: models of multi-modal interfaces and operator skill development	interfaces operator	Y
14	Modeling and Analysis: formal models that support task execution with success guarantees for human–robot systems	formal models	Y
15	Modeling and Analysis: new geometric and physical models that capture uncertainty and allow efficient construction of robust task plans	geometric physical models	Y
16	Modeling and Analysis: social, behavioral, and economic models to support analysis and prediction of long-term impacts of co-robots	impacts of co-robots	Y
17	Design and Materials: physical co-robot designs that enhance the safety and comfort of the human during collaborative task execution	safety comfort	Y
18	Design and Materials: compliant actuation methods	compliant actuation	Y
19	Design and Materials: novel approaches and mechanisms for actuation and robot mobility	actuation mobility	Y
20	Design and Materials: soft structures with embedded power, actuation, sensing, and computation	structures computation	Y
21	Design and Materials: system-level design and engineering	System level	Y
22	Design and Materials: optimization of kinematic and dynamic properties of co-robots	kinematic dynamic	Y
23	Design and Materials: miniaturization of sensors and robots	miniaturization	Y
24	Design and Materials: manufacturability, cost, and life cycle analysis	manufacturability cost life cycle	Y
25	Design and Materials: wearable robots and smart clothing capable of biometric monitoring and first aid	wearable and smart clothing	Y
26	Communication and Interfaces: research in human cognition, communication, and natural language processing	cognition communication natural language	Y

No.	Content	Keyword	Included
		processing	
27	Communication and Interfaces: language understanding and production, communication through physical contact and brain-machine interfaces	language communication	Y
28	Communication and Interfaces: computational algorithms and architectures for analyzing, understanding, and generating speech and other communicative forms like gestures and haptic displays	algorithms	Y
29	Planning and Control: motion or task planning methods with success guarantees	guarantees	Y
30	Planning and Control: provably correct planning methods	planning	Y
31	Planning and Control: models and algorithms to efficiently represent the structure of search spaces to speed planning	structure of search spaces	Y
32	Planning and Control: generation of legible motions	motions	Y
33	Planning and Control: optimal control of hybrid systems including human-robot systems	hybrid	Y
34	Planning and Control: real-time planning with kinematic and dynamic models	kinematic and dynamic models	Y
35	Planning and Control: human-guided planning	human-guided	Y
36	Planning and Control: fault-tolerant planning	fault-tolerant	Y
37	Planning and Control: real-time fault diagnosis and replanning	diagnosis replanning continuous	Y
38	Planning and Control: continuous calibration and adaptation of kinematic and dynamic models	calibration and adaptation of kinematic and dynamic models	Y
39	Planning and Control: formal methods for planning	formal methods for planning	Y
40	Planning and Control: stability of hybrid local-central controllers like both that arise in exoskeletons and smart prosthetics	stability of hybrid local- central controllers mimicking	Y
41	Planning and Control: controllers that mimic human learning, reasoning, and action planning	human learning reasoning and action planning	Y
42	Artificial Intelligence: mechanisms of human	reasoning and	Y

No.	Content	Keyword	Included
	reasoning and action planning	action planning integrated	
43	Artificial Intelligence: problem-solving architectures that integrate reasoning, perceptual, motor, and natural language capabilities	reasoning, perceptual, motor, and natural language cognition and	Y
44	Artificial Intelligence: models of human cognition and acquisition of contextual knowledge	acquisition of contextual knowledge	Y
45	Artificial Intelligence: systems that integrate robotic and artificial intelligence planning with learning and navigation for human–robot teams	learning and navigation	Y
46	Artificial Intelligence: research in specialties supporting the expansion of robot capabilities like multi-agent systems, human and machine cognition, and developmental science	expansion of capabilities	Y
47	Artificial Intelligence: knowledge representation	knowledge representation	Y
48	Cognition and Learning: machine cognition and cognitive prediction	cognition prediction	Y
49	Cognition and Learning: models of human or animal cognition	human or animal cognition	Y
50	Cognition and Learning: cognitive prostheses that extend human cognitive capabilities	cognitive prostheses	Y
51	Cognition and Learning: shared mental models for human–robot teams	shared mental	Y
52	Cognition and Learning: systems that learn from personal experience or from other robots’ experiences	learn experience	Y
53	Cognition and Learning: cognitive prostheses	cognitive	Y
54	Cognition and Learning: hybrid architectures that integrate different methods like deductive, probabilistic, case-based, and symbolic reasoning	integrate	Y
55	Algorithms and Hardware: design of data structures, algorithms, and computing hardware including GPUs and FPGAs for all topics above to achieve real-time, interactive performance	data structures, algorithms, and computing hardware	Y
56	Algorithms and Hardware: methods that support scaling up of problem sizes; for example, a single operator controls very large teams of robots	scaling up of problem sizes	Y
57	Application-Inspired: new types of sensors needed	new types of	Y

No.	Content	Keyword	Included
	for new types of applications	applications	
58	Application-Inspired: research topics peculiar to healthcare, marine, surveillance, mining, household, agriculture, and nano-robots	healthcare	Y
59	Application-Inspired: neural interfaces, signal processing, and control methods for intelligent prosthetic devices	prosthetic	Y
60	Platform-Specific: issues peculiar to specific platforms and operating domains including micro- and nano-robots, humanoid robots, networked multi-robot teams, Robot Operating Systems, exoskeletons, prosthetic devices, households	specific platforms	Y
61	Platform-Specific: assembly lines	assembly lines	Y
62	Assistive Technologies: enabling humans to amplify or compensate for their capabilities, with systems that interpret their intent, make context-based decisions, and allow people to operate beyond their diminished or normal physical, cognitive, or sensory capabilities, including prosthetics and exo-skeletal augmentation	intent interpretation	Y
63	Assistive Technologies: methods to use new environmental monitoring technologies and make decisions to improve human quality of life	environmental monitoring	Y
64	STEM Education: Research on robotic technologies that will enable the development of interactive and adaptive learning environments for learners of all ages, across all domains; and preparation of the next generation of researchers to confront new challenges in data-enabled robotic technologies and science (e.g., co-robot systems that support experimental workflow design, data ubiquity, and personalized learning)	interactive and adaptive learning environments	Y
Plan 2: National Network for Manufacturing Innovation			
65	Assistive and soft robotics: military units: Robots carrying heavy payloads over uneven terrain	payloads	Y
66	Assistive and soft robotics: military units: Automated materials handling of sensitive spare parts	automated materials	Y
67	Assistive and soft robotics: Soft Robotic Commercial applications: Prosthetics, surgery, assistance to the elderly	prosthetics, surgery, assistance to the elderly	Y

No.	Content	Keyword	Included
68	Assistive and soft robotics: Soft Robotic Commercial applications: Simulation and modeling	simulation and modeling	Y
69	Assistive and soft robotics: Soft Robotic Commercial applications: Food inspection, food processing, and picking and placing food items	food inspection, food processing, picking and placing food	Y
Plan 3: NASA Technology Roadmaps TA 4: Robotics and Autonomous Systems			
70	Robotics and Autonomous System: Sensing and Perception: 3D Sensing: 3D Range Imaging Sensors for Surface Mobility	surface Mobility	Y
71	Robotics and Autonomous System: Sensing and Perception: 3D Sensing: 3D Range Imaging Sensors for Above-Surface Mobility	above-Surface mobility	Y
72	Robotics and Autonomous System: Sensing and Perception: 3D Sensing: 5D Range Imaging Sensors for Manipulation	3D range imaging for manipulation	Y
73	Robotics and Autonomous System: Sensing and Perception: 3D Sensing: In Situ Camera Geometric Calibration Diagnostics and Self-Calibration	diagnostics and self-calibration	Y
74	Robotics and Autonomous System: Sensing and Perception: State Estimation: Vision-Based Aiding of Dead Reckoning for Navigation of Surface Vehicles	dead reckoning for surface vehicles	Y
75	Robotics and Autonomous System: Sensing and Perception: State Estimation: Map-Based Position Estimation for Navigation of Surface Vehicles	position estimation for surface vehicles	Y
76	Robotics and Autonomous System: Sensing and Perception: State Estimation: Vision-Based Aiding of Dead Reckoning for Above-Surface Vehicles	dead reckoning for above-surface vehicles	Y
77	Robotics and Autonomous System: Sensing and Perception: State Estimation: Map-Based Position Estimation for Navigation of Above-Surface Vehicles	position estimation for above-surface vehicles	Y
78	Robotics and Autonomous System: Sensing and Perception: State Estimation: Radio Frequency (RF) Navigation Aiding for Above-Surface Vehicles	RF for above-surface vehicles	Y
79	Robotics and Autonomous System: Sensing and Perception: State Estimation: Altimeter for Small Above-Surface Vehicles	altimeter for small above-surface vehicles	Y

No.	Content	Keyword	Included
80	Robotics and Autonomous System: Sensing and Perception: State Estimation: Manipulator State Estimation	manipulator state estimation	Y
81	Robotics and Autonomous System: Sensing and Perception: State Estimation: Manipulation Object State Estimation	manipulation object state estimation	Y
82	Robotics and Autonomous System: Sensing and Perception: Onboard Mapping: Terrain Mapping for Surface Vehicles	terrain mapping for surface vehicles	Y
83	Robotics and Autonomous System: Sensing and Perception: Onboard Mapping: Terrain Mapping for Above-Surface Vehicles	terrain mapping for above- surface vehicles	Y
84	Robotics and Autonomous System: Sensing and Perception: Onboard Mapping: Landmark Mapping from Image Sequences and Other Navigation Data	image sequences	Y
85	Robotics and Autonomous System: Sensing and Perception: Onboard Mapping: 3D Modeling from Multiple Observations	3D modeling	Y
86	Robotics and Autonomous System: Sensing and Perception: Object, Event, and Activity Recognition: Natural Object Recognition	natural object recognition	Y
87	Robotics and Autonomous System: Sensing and Perception: Object, Event, and Activity Recognition: Human-Made Object Recognition	human-made object recognition	Y
88	Robotics and Autonomous System: Sensing and Perception: Object, Event, and Activity Recognition: Event Recognition	event recognition	Y
89	Robotics and Autonomous System; Sensing and Perception: Force and Tactile Sensing: Space-Qualifiable Force and Torque Sensors	space- qualifiable force and torque sensors	Y
90	Robotics and Autonomous System: Sensing and Perception: Force and Tactile Sensing: Space-Qualifiable Tactile Sensors	space- qualifiable tactile sensors	Y
91	Robotics and Autonomous System: Sensing and Perception: Onboard Science Data Analysis	onboard science data analysis	Y
92	Robotics and Autonomous System: Mobility: Extreme-Terrain Mobility: Rappelling Mobility Systems	rappelling	Y
93	Robotics and Autonomous System: Mobility: Extreme-Terrain Mobility: Climbing Mobility Systems	climbing	Y

No.	Content	Keyword	Included
94	Robotics and Autonomous System: Mobility: Extreme-Terrain Mobility: Soft/Friable Terrain Mobility Systems	soft/friable terrain	Y
95	Robotics and Autonomous System: Mobility: Below-Surface Mobility: Subsurface Access Through Natural Cavities	natural cavities	Y
96	Robotics and Autonomous System: Mobility: Below-Surface Mobility: Subsurface Access Through Human-Made Holes	human-made holes	Y
97	Robotics and Autonomous System: Mobility: Below-Surface Mobility: Burrowing Mobility	burrowing	Y
98	Robotics and Autonomous System: Mobility: Below-Surface Mobility: Long-Endurance Submerged Mobility	submerged	Y
99	Robotics and Autonomous System: Mobility: Above-Surface Mobility: Ballistic Systems	ballistic	Y
100	Robotics and Autonomous System: Mobility: Above-Surface Mobility: Static-Lift Systems	static-lift	Y
101	Robotics and Autonomous System: Mobility: Above-Surface Mobility: Dynamic-Lift Systems	dynamic-lift	Y
102	Robotics and Autonomous System: Mobility: Above-Surface Mobility: Power-Lift Systems	power-lift	Y
103	Robotics and Autonomous System: Mobility: Small-Body and Microgravity Mobility: Free- Floating Robots	free-floating	Y
104	Robotics and Autonomous System: Mobility: Small-Body and Microgravity Mobility: Hopping/Tumbling Surface Robots	hopping/tumblin g	Y
105	Robotics and Autonomous System: Mobility: Small-Body and Microgravity Mobility: Anchoring Robots	anchoring	Y
106	Robotics and Autonomous System: Mobility: Small-Body and Microgravity Mobility: Wheeled/Tracked/Hybrid Robots	wheeled/tracked /hybrid	Y
107	Robotics and Autonomous System: Mobility: Surface Mobility: Mobility Subsystem for Crewed Surface Transport	crewed surface transport	Y
108	Robotics and Autonomous System: Mobility: Surface Mobility: Mobility System for Uncrewed Surface Transport	uncrewed surface transport	Y
109	Robotics and Autonomous System: Mobility: Robot Navigation: Adaptive Autonomous Surface Navigation	surface navigation	Y

No.	Content	Keyword	Included
110	Robotics and Autonomous System: Mobility: Robot Navigation: Autonomous Navigation for Tethered Systems	autonomous navigation	Y
111	Robotics and Autonomous System: Mobility: Robot Navigation: Low-Altitude Above-Surface Navigation	low-altitude above-surface navigation	Y
112	Robotics and Autonomous System: Mobility: Robot Navigation: Below-Surface Navigation	below-surface navigation	Y
113	Robotics and Autonomous System: Mobility: Robot Navigation: Small-Body/Microgravity Navigation	small- body/microgravi ty navigation	Y
114	Robotics and Autonomous System: Mobility: Collaborative Mobility: Collaborative Mobility Algorithms	collaborative mobility	Y
115	Robotics and Autonomous System: Mobility: Mobility Components: Wheels for Planetary Surfaces	wheels for planetary surfaces	Y
116	Robotics and Autonomous System: Mobility: Mobility Components: Actuators for Mobile Robots	actuators for mobile robots	Y
117	Robotics and Autonomous System: Mobility: Mobility Components: Terrain Adhesion	terrain adhesion	Y
118	Robotics and Autonomous System: Mobility: Mobility Components: Sensing Terra-Mechanical Properties	sensing terra- mechanical properties	Y
119	Robotics and Autonomous System: Manipulation: Manipulator Components: Actuators	actuators	Y
120	Robotics and Autonomous System: Manipulation: Manipulator Components: Lightweight Structures	lightweight	Y
121	Robotics and Autonomous System: Manipulation: Manipulator Components: Motor Controllers	motor	Y
122	Robotics and Autonomous System: Manipulation: Manipulator Components: Manipulator Concepts	manipulator	Y
123	Robotics and Autonomous System: Manipulation: Dexterous Manipulation: Dexterous Manipulator Arms	dexterous manipulator arms	Y
124	Robotics and Autonomous System: Manipulation: Dexterous Manipulation: Dexterous Manipulator End Effectors	manipulator end effectors	Y
125	Robotics and Autonomous System: Manipulation: Modeling of Contact Dynamics	contact dynamics	Y
126	Robotics and Autonomous System: Manipulation: Mobile Manipulation: Mobile Manipulation	mobile manipulation	Y

No.	Content	Keyword	Included
127	Robotics and Autonomous System: Manipulation: Collaborative Manipulation: Collaborative Manipulation	collaborative manipulation	Y
128	Robotics and Autonomous System: Manipulation: Sample Acquisition and Handling: Robotic Drilling	drilling	Y
129	Robotics and Autonomous System: Manipulation: Sample Acquisition and Handling: Deep Robotic Drilling	deep drilling	Y
130	Robotics and Autonomous System: Manipulation: Sample Acquisition and Handling: Surface/Shallow Robotic Sample Acquisition	surface/shallow sample acquisition	Y
131	Robotics and Autonomous System: Manipulation: Sample Acquisition and Handling: Subsurface Robotic Sample Acquisition	subsurface sample acquisition	Y
132	Robotics and Autonomous System: Manipulation: Sample Acquisition and Handling: Sample Handling	sample handling	Y
133	Robotics and Autonomous System: Manipulation: Sample Acquisition and Handling: Regolith/Volatiles Sample Handling and Transfer	sample handling and transfer	Y
134	Robotics and Autonomous System: Manipulation: Sample Acquisition and Handling: Robotic Excavation	excavation	Y
135	Robotics and Autonomous System: Manipulation: Grappling: Grappling	grappling	Y
136	Robotics and Autonomous System: Human– System Interaction: Multi-Modal Interaction: Virtual Environment	virtual environment	Y
137	Robotics and Autonomous System: Human– System Interaction: Multi-Modal Interaction: Multi-Modal Dialogue	multi-modal dialogue	Y
138	Robotics and Autonomous System: Human– System Interaction: Supervisory Control	supervisory	Y
139	Robotics and Autonomous System: Human– System Interaction: Proximate Interaction: Robot- to-Suit Interfaces	robot-to-suit interfaces	Y
140	Robotics and Autonomous System: Human– System Interaction: Proximate Interaction: Intent Recognition and Reaction	intent recognition and reaction for proximate interaction	Y
141	Robotics and Autonomous System: Human–	feedback	Y

No.	Content	Keyword	Included
	System Interaction: Proximate Interaction: Feedback Displays for Proximate Interaction	displays	
142	Robotics and Autonomous System: Human–System Interaction: Intent Recognition and Reaction	intent recognition and reaction	Y
143	Robotics and Autonomous System: Human–System Interaction: Distributed Collaboration and Coordination: Interaction Architecture	interaction architecture	Y
144	Robotics and Autonomous System: Human–System Interaction: Distributed Collaboration and Coordination: In-Line Performance Metrics	in-line performance metrics	Y
145	Robotics and Autonomous System: Human–System Interaction: Distributed Collaboration and Coordination: Notification and Summarization	notification and summarization	Y
146	Robotics and Autonomous System: Human–System Interaction: Common Human–System Interfaces	common human–system interfaces	Y
147	Robotics and Autonomous System: Human–System Interaction: Safety, Trust, and Interfacing of Robotic/Human Proximity Operations	safety, trust, and interfacing	Y
148	Robotics and Autonomous System: Human–System Interaction: Remote Interaction: Direct Teleoperation	direct teleoperation	Y
149	Robotics and Autonomous System: Human–System Interaction: Remote Interaction: Supervisory Control	supervisory control	Y
150	Robotics and Autonomous System: Human–System Interaction: Decision Support Tools for Remote Interaction	remote interaction	Y
151	Robotics and Autonomous System: System-Level Autonomy: System Health Management: Onboard Real-Time Fault Detection, Isolation, and Recovery	onboard FDIR	Y
152	Robotics and Autonomous System: System-Level Autonomy: System Health Management: Ground-Based Fault Detection, Isolation, and Recovery (FDIR)	ground-based FDIR	Y
153	Robotics and Autonomous System: System-Level Autonomy: System Health Management: Integrated Vehicle Health Management (IVHM)	IVHM	Y
154	Robotics and Autonomous System: System-Level Autonomy: Activity Planning, Scheduling, and Execution: On board Real-Time Planning and	onboard real- time planning and scheduling	Y

No.	Content	Keyword	Included
	Scheduling		
155	Robotics and Autonomous System: System-Level Autonomy: Activity Planning, Scheduling, and Execution: Ground-Based Mixed Initiative Planning and Scheduling	ground-based mixed initiative planning and scheduling	Y
156	Robotics and Autonomous System: System-Level Autonomy: Activity Planning, Scheduling, and Execution: Plan/ Sequence/Schedule Verification Tools	plan/ sequence/schedu le verification	Y
157	Robotics and Autonomous System: System-Level Autonomy: Activity Planning, Scheduling, and Execution: Onboard Executives	onboard executives	Y
158	Robotics and Autonomous System: System-Level Autonomy: Activity Planning, Scheduling, and Execution: State Management	state management	Y
159	Robotics and Autonomous System: System-Level Autonomy: Autonomous Guidance and Control	guidance and control	Y
160	Robotics and Autonomous System: System-Level Autonomy: Multi-Agent Coordination: Multi- Agent Coordination	multi-agent coordination	Y
161	Robotics and Autonomous System: System-Level Autonomy: Adjustable Autonomy	adjustable autonomy	Y
162	Robotics and Autonomous System: System-Level Autonomy: Terrain Relative Navigation	terrain relative navigation	Y
163	Robotics and Autonomous System: System-Level Autonomy: Path and Motion Planning with Uncertainty	path and motion planning	Y
164	Robotics and Autonomous System: System-Level Autonomy: Automated Data Analysis for Decision Making: Autonomous Decision Making	autonomous decision making	Y
165	Robotics and Autonomous System: Autonomous Rendezvous and Docking: Relative Navigation Sensors: 3D Imaging Sensor	3D imaging	Y
166	Robotics and Autonomous System: Autonomous Rendezvous and Docking: Relative Navigation Sensors: Visible Camera	visible camera	Y
167	Robotics and Autonomous System: Autonomous Rendezvous and Docking: Relative Navigation Sensors: Longwave Infrared (LWIR) Camera	LWIR	Y
168	Robotics and Autonomous System: Autonomous Rendezvous and Docking: Guidance, Navigation, and Control Algorithms: Rendezvous Targeting	rendezvous targeting	Y
169	Robotics and Autonomous System: Autonomous	operations/captu	Y

No.	Content	Keyword	Included
	Robotics and Autonomous System: Autonomous Rendezvous and Docking: Guidance, Navigation, and Control Algorithms: Proximity Operations/Capture/Docking Guidance	re/docking guidance	
170	Robotics and Autonomous System: Autonomous Rendezvous and Docking: Docking and Capture Mechanisms and Interfaces: Integrated Docking and Automated Rendezvous System Design	integrated docking and automated rendezvous	Y
171	Robotics and Autonomous System: Autonomous Rendezvous and Docking: Docking and Capture Mechanisms and Interfaces: Docking System for Exploration	docking	Y
172	Robotics and Autonomous System: Autonomous Rendezvous and Docking: Mission and System Managers for Autonomy and Automation	mission and system managers	Y
173	Robotics and Autonomous System: Systems Engineering: Modularity, Commonality, and Interfaces: Refueling Interfaces	refueling interfaces	Y
174	Robotics and Autonomous System: Systems Engineering: Modularity, Commonality, and Interfaces: Modular Serviceable Interfaces	modular serviceable interfaces	Y
175	Robotics and Autonomous System: Systems Engineering: Modularity, Commonality, and Interfaces: Self-Assembling and Configuration Features	self-assembling and configuration	Y
176	Robotics and Autonomous System: Systems Engineering: Modularity, Commonality, and Interfaces: Marsupial Robot Interfaces	marsupial interfaces	Y
177	Robotics and Autonomous System: Systems Engineering: Verification and Validation of Complex Adaptive Systems: Verification and Validation of Complex Adaptive Systems	complex adaption	Y
178	Robotics and Autonomous System: Systems Engineering: Robot Modeling and Simulation: End-to-End Systems Modeling	end-to-end	Y
179	Robotics and Autonomous System: System Engineering: Robot Modeling and Simulation: Modeling of Contact Dynamics	contact dynamics	Y
180	Robotics and Autonomous System: Systems Engineering: Robot Modeling and Simulation: Dynamic Simulation	dynamic simulation	Y
181	Robotics and Autonomous System: Systems Engineering: Robot Modeling and Simulation: Granular Media Simulation	granular media	Y

No.	Content	Keyword	Included
182	Robotics and Autonomous System: Systems Engineering: Robot Software: Robotic Architecture and Frameworks	architecture and frameworks	Y
183	Robotics and Autonomous System: Systems Engineering: Robot Software: Standardized Messaging Protocols	messaging protocols	Y
184	Robotics and Autonomous System: Systems Engineering: Robot Software: Model-Based Robotic Software	model-based robotic software	Y
185	Robotics and Autonomous System: Systems Engineering: Safety and Trust: Safety, Trust, and Interfacing Proximity Operation Technologies	safety, trust, and proximity operation technologies	Y
Plan 4: A Roadmap for U.S. Robotics: From Internet to Robotics			
186	Robotics in Manufacturing: Learning and Adaptation	learning and adaptation in manufacturing modeling,	Y
187	Robotics in Manufacturing: Modeling, Analysis, Simulation, and Control	analysis, simulation, and control	Y
188	Robotics in Manufacturing: Formal Methods	formal methods in manufacturing control and	Y
189	Robotics in Manufacturing: Control and Planning	planning in manufacturing perception in	Y
190	Robotics in Manufacturing: Perception	manufacturing mechanisms and	Y
191	Robotics in Manufacturing: Novel Mechanisms and High-Performance Actuators	actuators in manufacturing human–robot	Y
192	Robotics in Manufacturing: Human–Robot Interaction	interaction in manufacturing architecture and	Y
193	Robotics in Manufacturing: Architecture and Representations	representations in manufacturing measurement	Y
194	Robotics in Manufacturing: Measurement Science	science	Y
195	Robotics in Manufacturing: “Cloud” Robotics and	cloud and	Y

No.	Content	Keyword	Included
	Automation for Manufacturing	automation for manufacturing architecture and	
196	Healthcare and Medical Robotics: Architecture and Representations	representations in healthcare and medical	Y
197	Healthcare and Medical Robotics: Formal Methods	formal methods in healthcare and medical	Y
198	Healthcare and Medical Robotics: Control and Planning	control and planning in healthcare and medical	Y
199	Healthcare and Medical Robotics: Perception	perception in healthcare and medical	Y
200	Healthcare and Medical Robotics: Robust, High-Fidelity Sensors	robust, high-fidelity in healthcare and medical	Y
201	Healthcare and Medical Robotics: Novel Mechanisms and High-Performance Actuators	mechanisms and actuators in healthcare and medical	Y
202	Healthcare and Medical Robotics: Learning and Adaptation	learning and adaptation in healthcare and medical	Y
203	Healthcare and Medical Robotics: Physical Human–Robot Interaction	physical human–robot interaction in healthcare and medical	Y
204	Healthcare and Medical Robotics: Interaction Algorithms for Socially Assistive Robots	interaction algorithms	Y
205	Healthcare and Medical Robotics: Modeling, Simulation, and Analysis	modeling, simulation, and analysis	Y
206	Service Robotics: Architecture and Representations	architecture and representations in service	Y
207	Service Robotics: Control and Planning	control and planning in	Y

No.	Content	Keyword	Included
208	Service Robotics: Perception	service perception in service	Y
209	Service Robotics: Robust, High-Fidelity Sensors	robust, high- fidelity in service	Y
210	Service Robotics: Novel Mechanisms and High-Performance Actuators	mechanisms and actuators in service	Y
211	Service Robotics: Learning and Adaptation	learning and adaptation in service	Y
212	Service Robotics: Physical Human–Robot Interaction	physical human–robot interaction in service	Y
213	Service Robotics: Socially Interactive Robots	socially interactive	Y
214	Robot Applications in Space: Sensing and Perception	sensing and perception	Y
215	Robot Applications in Space: Mobility	mobility in space	Y
216	Robot Applications in Space: Manipulation Technology	manipulation technology	Y
217	Robot Applications in Space: Human–System Interaction	human–system interaction	Y
218	Robot Applications in Space: Autonomy	autonomy in space	Y
219	Robot Applications in Defense: Interoperability	interoperability in defense	Y
220	Robot Applications in Defense: Autonomy	autonomy in defense	Y
221	Robot Applications in Defense: Communications	communications	Y
222	Robot Applications in Defense: Propulsion and Power	propulsion power	Y
223	Robot Applications in Defense: Manned–Unmanned Teaming	manned– unmanned teaming	Y
Government: European Union			
Plan 1: Preparing the Commission for Future Opportunities–Foresight Network Fiches (2030)			
224	Brain-inspired technologies: novel, low-power	neuromorphic	Y

No.	Content	Keyword	Included
	neuromorphic multi-processor systems and brain-inspired robotics	multi-processor	
225	Brain-inspired technologies: conscious robots	consciousness	Y
226	Brain-inspired technologies: advanced machine learning and decision-making theory and systems	machine learning and decision making	Y
227	Brain-inspired technologies: human-computer interaction	human-computer interaction	Y
Plan 2: Strategic Research Agenda for Robotics in Europe (2014–2020)			
228	Manufacturing: Accurate indoor positioning systems for mobile manipulators, particularly in dynamic environments.	indoor positioning	Y
229	Manufacturing: Sensor based safety systems to enhance human-robot interaction.	interaction safety	Y
230	Manufacturing: Higher levels of realism in system modeling to speed application development.	system modeling	Y
231	Manufacturing: Reactive planning and control able to operate a robot safely in real industrial environments.	reactive planning and control	Y
232	Healthcare: Improved teleoperation and physical interaction	teleoperation and physical interaction	Y
233	Healthcare: Miniaturized mechanical systems and sensing	miniaturized	Y
234	Healthcare: Multi-degree-of-freedom tactile feedback	tactile feedback	Y
235	Healthcare: Inherently safe systems	Inherently safe	Y
236	Healthcare: Monitoring of patient condition and improved data interpretation during procedures	monitoring and interpretation	Y
237	Agriculture: Predictive and distributed planning	predictive planning	Y
238	Agriculture: Crop and livestock assessment and recognition of condition	crop and livestock assessment	Y
239	Agriculture: Produce handling and processing	produce handling and processing	Y
240	Agriculture: Synchronization and coordination between farm vehicles and with processing equipment	coordination	Y
241	Agriculture: In-field localization and	localization	Y

No.	Content	Keyword	Included
	communication	communication	
242	Civil: Mission and task planning, particularly between multiple modalities.	multiple modalities	Y
243	Civil: Sensing, perception, and interpretation of the environment.	sensing perception interpretation	Y
244	Civil: Cooperative and distributed planning for multiple robots	cooperative planning	Y
245	Civil: Cognitive technologies for assessment and high-level interpretation	cognitive	Y
246	Civil: Human–robot interaction	human–robot interaction	Y
247	Commercial: Safety integrated design processes	safety integrated physical	Y
248	Commercial: Physical human–robot interaction	human–robot interaction	Y
249	Commercial: Long-term autonomy	autonomy	Y
250	Commercial: Lightweight robust mechanical structures	mechanical structures	Y
251	Logistics and Transport: Interaction technology	Interaction	Y
252	Logistics and Transport: Compliant mechanical systems	Compliant	Y
253	Logistics and Transport: 3D environment interpretation	3D environment interpretation	Y
254	Logistics and Transport: Task planning and optimization	planning and optimization	Y
255	Consumer: Improved sensing of the surrounding environment.	sensing of the surrounding environment	Y
256	Consumer: Improved interpretation of the environment	interpretation	Y
257	Consumer: Low-cost sensing	Low-cost sensing	Y
258	Consumer: Physical human–robot interfaces	interfaces	Y
259	Consumer: Improved energy efficient systems	energy efficient	Y
Plan 3: ESA Technology Tree			
260	Automation, Telepresence, and Robotics: Applications and concepts: Planetary Exploration	planetary exploration	Y
261	Automation, Telepresence, and Robotics: Applications and concepts: Orbital Systems	orbital systems	Y
262	Automation, Telepresence, and Robotics: Automation and robotics systems: Manipulation Systems	manipulation systems	Y

No.	Content	Keyword	Included
263	Automation, Telepresence, and Robotics: Automation and robotics systems: Mobility Systems	mobility systems	Y
264	Automation, Telepresence, and Robotics: Automation and robotics systems: Payload Automation Systems	payload automation	Y
265	Automation, Telepresence, and Robotics: Automation and robotics components and technologies: Perception	perception	Y
266	Automation, Telepresence, and Robotics: Automation and robotics components and technologies: Control, Autonomy, and Intelligence	control, autonomy, and intelligence	Y
267	Automation, Telepresence, and Robotics: Automation and robotics components and technologies; Motion and Actuation	motion and actuation	Y
268	Automation, Telepresence, and Robotics: Automation and robotics components and technologies: Robot–User Interfacing	user interfacing	Y
269	Automation, Telepresence, and Robotics: Automation and robotics components and technologies: Robot Ground Testing	ground testing	Y
Government: Japan			
Plan 1: Japan’s Robot Strategy: Vision, Strategy, Action Plan			
270	Artificial Intelligence: data-driven artificial intelligence	data-driven	Y
271	Artificial Intelligence: knowledge representing and reasoning artificial intelligence	knowledge representing reasoning	Y
272	Artificial Intelligence: research and development of such technology as brain-like artificial intelligence	brain-like	Y
273	Sensor and Recognition System: environment-learning vision sensor	environment-learning vision	Y
274	Sensor and Recognition System: voice processing and recognition technology under low signal-to-noise ratio	voice	Y
275	Sensor and Recognition System: smell sensor	smell	Y
276	Sensor and Recognition System: distributed touch sensor system	touch	Y
277	Sensor and Recognition System: sensor fusion system integrating these sensors	sensor fusion	Y
278	Mechanism, Actuator, and their Control System:	PWR	Y

No.	Content	Keyword	Included
279	low cost and high power-to-weight ratio (PWR) Mechanism, Actuator, and their Control System: multi-degree-of-freedom actuators imitating the human joint	multi-degree-of-freedom actuators	Y
280	Mechanism, Actuator, and their Control System: high-molecular lightweight artificial muscle and a control theory for smooth control of such a highly nonlinear system	muscle control	Y
281	Mechanism, Actuator, and their Control System: general-purpose hand system for bilateral control	general-purpose hand	Y
282	OS and Middleware: simulators simulate working environment	simulated working environment	Y
283	OS and Middleware: OS and middleware that can work with simulators	middleware simulators	Y
284	OS and Middleware: general-purpose OS and middleware that can be used as the standards	middleware standards	Y
285	Security and safety evaluation and standard: safety evaluation and risk prediction	prediction	Y
286	Security and safety evaluation and standard: establishment and standardization of test methods	test	Y
287	Security and safety evaluation and standard: rules for handling information collected by robots	rules	Y
288	Security and safety evaluation and standard: examination and research and development of security technology	security	Y
289	Technology converted from other broad areas: long-life, compact, and lightweight battery technology	battery	Y
290	Technology converted from other broad areas: wireless electricity supply technology	electricity supply	Y
291	Technology converted from other broad areas: communication technology	communication	Y
292	Technology converted from other broad areas: material technology	material	Y
Plan 2: White Paper on Robotization of Industry, Business, and Our Life (2014)			
293	Industrial Robots: mechanical technology	mechanical	N
294	Industrial Robots: material technology	material	N
295	Lifestyle and Service Field Robotization Industries: safe engineering	safe	N
296	Lifestyle and Service Field Robotization Industries: spacing intelligence	spacing	N

No.	Content	Keyword	Included
297	Lifestyle and Service Field Robotization Industries: service engineering	service	N
298	Lifestyle and Service Field Robotization Industries: humanoids	humanoids	N
299	Lifestyle and Service Field Robotization Industries: BMI	BMI	N
300	Lifestyle and Service Field Robotization Industries: cognitive development systems	cognitive	N
301	Lifestyle and Service Field Robotization Industries: life design	life	N
302	Lifestyle and Service Field Robotization Industries: elderly people	elderly people	Y
Government: United Kingdom of Great Britain and Northern Ireland			
Plan 1: Robotics and Autonomous Systems (2020)			
303	Robotics and Autonomous Systems: Aerospace: aerospace robotic systems	aerospace	Y
304	Robotics and Autonomous Systems: Aerospace: unmanned aircraft systems: collision detection and avoidance systems	collision detect and avoid systems	Y
305	Robotics and Autonomous Systems: Offshore Energy: Autonomous marine robots	Autonomous marine	Y
306	Robotics and Autonomous Systems: Offshore Energy: underwater robotics testbed	underwater testbed	Y
307	Robotics and Autonomous Systems: Nuclear Robotics	nuclear	Y
308	Robotics and Autonomous Systems: Intelligent Mobility: low-speed autonomous pods	low-speed autonomous pods	Y
309	Robotics and Autonomous Systems: Farms of the Future	farms of the future	Y
Plan 2: UK-RAS Network			
310	Transport: machine vision and perception	vision and perception	Y
311	Transport: large-scale navigation	large-scale navigation spatial	Y
312	Transport: spatial linguistics and exploration and planning	linguistics and exploration and planning	Y
313	Transport: scene understanding	scene understanding	Y

No.	Content	Keyword	Included
314	Transport: control and verification	control and verification	Y
315	Transport: high-fidelity scalable simulation environments	simulation environments	Y
316	Healthcare: miniaturized robots for MIS and targeted therapy with micro-instruments and smart actuators supported by new materials	miniaturized and smart	Y
317	Healthcare: micro-fabrication and rapid prototyping technologies	micro-fabrication and rapid prototyping	Y
318	Healthcare: bioinspired and soft robotics	bioinspired and soft	Y
319	Healthcare: self-assembled robots with integrated electronics, actuators, and sensors embedded during production	self-assembled	Y
320	Healthcare: assisted robotics including home/personal use, nursing/caring, paramedical, social activation (for dementia and cognitive disabilities) and smart prostheses/ortheses	assistance	Y
321	Manufacturing: professional service robots	professional service	Y
322	Manufacturing: new RAS platforms for green manufacturing	green manufacturing	Y
323	Manufacturing: collaboration and robot integration	collaboration and integration	Y
324	Unmanned Systems: increased autonomy	increased autonomy	Y
325	Unmanned Systems: assessing environmental obstacles, hazards, and constraints	assessing environmental obstacles, hazards, and constraints	Y
326	Unmanned Systems: sensing and understanding complex, dynamic environments	sensing and understanding environments	Y
327	Unmanned Systems: navigation under extreme conditions	navigation under extreme conditions	Y
328	Unmanned Systems: improved and resilient communications	improved and resilient communications	Y
329	Unmanned Systems: more efficient capabilities	modularity,	Y

No.	Content	Keyword	Included
	through modularity, commonality, and interoperability	commonality and interoperability	
330	Underpinning RAS technologies: multi-modal and multi-scale RAS	multi-modal and multi-scale RAS learning,	Y
331	Underpinning RAS technologies: robot learning, anthropomorphic, and bio-inspired designs	anthropomorphic and bio-inspired	Y
332	Underpinning RAS technologies: micro-engineering and fabrication	micro-engineering and fabrication	Y
333	Underpinning RAS technologies: smart actuators and sensors	actuators and sensors	Y
334	Underpinning RAS technologies: embedded intelligence	embedded intelligence	Y
335	Underpinning RAS technologies: robot vision, perception, machine intelligence, software agents, control, and verification	vision, perception, machine intelligence, software agents, control and verification	Y
336	Underpinning RAS technologies: flexible adaptive manipulation, sensorimotor, social intelligence, and formal verification for ethical, legal, and safety issues	manipulation, sensorimotor, social intelligence and formal verification for ethical, legal, and safety	Y
337	Underpinning RAS technologies: integrated structures and electronics	integrated structures and electronics	Y
338	Underpinning RAS technologies: human–robot interaction, simulation, and teleoperation across scales	human–robot interaction, simulation and teleoperation across scales	Y
Plan 3: Science Landscape Seminar Reports: Robotics and Autonomous Systems			
339	Robotics and Autonomous Systems: effective regulation	effective regulation	Y

No.	Content	Keyword	Included
340	Robotics and Autonomous Systems: more test centers	test centers	Y
341	Robotics and Autonomous Systems: autonomous systems in aerospace and medicine industry	autonomous systems in aerospace and medicine	Y
342	Robotics and Autonomous Systems: Standards in Technology	Standards in Technology	Y
Government: Russian Federation			
Plan: О национальном центре развития технологий и базовых элементов робототехники			
343	робот военного	Military	N
344	робот специального	Special	N
345	робот двойного назначения	Dual-use	N
Government: Republic of France			
Plan: France Robots Initiatives			
346	Transport and logistics	transport and logistics	N
347	Defense and security	defense and security	N
348	Environment	environment	N
349	Intelligent machines	intelligent machines	N
350	Assistance to the person	assistance to the person	N
Government: People's Republic of China			
Plan 1: “十三五” 国家科技创新规划(2016)			
351	智能机器人-下一代机器人技术	next generation	Y
352	智能机器人-智能机器人学习与认知	learning and cognition	Y
353	智能机器人-人机自然交互与协作共融	interaction and cooperation	Y
354	智能机器人-机器人核心部件关键技术	core components	Y
355	智能机器人-工业机器人产业化	industrialization	Y
356	智能机器人-服务机器人产品化	commercialized	Y
357	智能机器人-特种机器人批量化应用	batch application	Y
Plan 2: 中国制造 2025 (2015)			
358	机器人-人机智能交互	human-computer interaction	Y

No.	Content	Keyword	Included
359	机器人-机器人本体	ontology	Y
360	机器人-减速器	reducer	Y
361	机器人-伺服电机	servo motor	Y
362	机器人-控制器	controller	Y
363	机器人-传感器	sensors	Y
364	机器人-驱动器	actuator	Y
		system	
365	机器人-系统集成设计制造	Integration design and manufacturing	Y
Plan 3: 国家中长期科技发展规划纲要 2006 - 2020 (2006)			
366	智能服务机器人-设计方法	design	Y
367	智能服务机器人-制造工艺	manufacturing	Y
368	智能服务机器人-智能控制	intelligent control	Y
		application	
369	智能服务机器人-应用系统集成	system integration	Y
370	智能服务机器人-智能服务机器人	intelligent service	Y
371	智能服务机器人-危险作业机器人	hazardous operation	Y
Plan 4: 机器人产业发展规划 (2016—2020 年) (2016)			
372	工业机器人产品-弧焊机器人-焊缝轨迹电弧跟踪	arc welding seam trajectory tracking	Y
373	工业机器人产品-弧焊机器人-高压接触感知	high pressure contact sensing	Y
374	工业机器人产品-弧焊机器人-焊缝坡口宽度电弧跟踪	arc width tracking of weld bead	Y
375	工业机器人产品-真空（洁净）机器人-真空环境下传动润滑	transmission lubrication	Y
376	工业机器人产品-真空（洁净）机器人-直驱控制	direct drive control	Y
377	工业机器人产品-真空（洁净）机器人-动态偏差检测与校正	dynamic deviation	Y
378	工业机器人产品-真空（洁净）机器人-碰撞检测与保护	collision detection and protection	Y
379	工业机器人产品-全自主编程智能工业机器人	Industry	Y

No.	Content	Keyword	Included
380	工业机器人产品-人机协作机器人	man-machine cooperation	Y
381	工业机器人产品-双臂机器人	dual-arm auxiliary	Y
382	工业机器人产品-重载 AGV-辅助磁导航	magnetic navigation	Y
383	工业机器人产品-重载 AGV-激光防碰	laser anti-collision	Y
384	工业机器人产品-重载 AGV-车体自举升	car body self-lifting	Y
385	工业机器人产品-消防救援机器人	fire rescue	Y
386	工业机器人产品-手术机器人	surgery	Y
387	工业机器人产品-智能型公共服务机器人	public service	Y
388	工业机器人产品-智能护理机器人	intelligent nursing	Y
389	机器人关键零部件-高精密减速器-高强度耐磨材料技术	wear-resistant materials	Y
390	机器人关键零部件-高精密减速器-加工工艺优化技术	processing optimization	Y
391	机器人关键零部件-高精密减速器-高速润滑技术	high speed lubrication	Y
392	机器人关键零部件-高精密减速器-高精度装配技术	high-precision assembly	Y
393	机器人关键零部件-高精密减速器-可靠性及寿命检测技术	reliability and life detection	Y
394	机器人关键零部件-高精密减速器-新型传动机理	transmission mechanism	Y
395	机器人关键零部件-高性能机器人专用伺服电机和驱动器-高磁性材料优化	magnetic material optimization	Y
396	机器人关键零部件-高性能机器人专用伺服电机和驱动器-一体化优化设计	integrated optimization	Y
397	机器人关键零部件-高性能机器人专用伺服电机和驱动器-加工装配工艺优化	process optimization	Y
398	机器人关键零部件-高性能机器人专用伺服电机和驱动器-高力矩直接驱动电机	high-torque direct drive motor	Y
399	机器人关键零部件-高性能机器人专用伺服电机和驱动器-盘式中空电机	disc hollow motor	Y
400	机器人关键零部件-高速高性能控制器-高性能关节伺服	joint Servo	Y
401	机器人关键零部件-高速高性能控制器-振动抑制技术	vibration suppression	Y

No.	Content	Keyword	Included
402	机器人关键零部件-高速高性能控制器-惯量动态补偿技术	inertia dynamic compensation	Y
403	机器人关键零部件-高速高性能控制器-多关节高精度运动解算及规划	multi-joint motion solution and planning controller	Y
404	机器人关键零部件-高速高性能控制器-开放式控制器软件开发平台技术	software development platform	Y
405	机器人关键零部件-传感器-关节位置传感器	joint position sensor	Y
406	机器人关键零部件-传感器-力矩传感器	torque sensor	Y
407	机器人关键零部件-传感器-视觉传感器	vision sensor	Y
408	机器人关键零部件-传感器-触觉传感器	tactile sensor	Y
409	机器人关键零部件-末端执行器-抓取与操作功能的多指灵巧手	multi-fingered dexterous hand	Y
410	机器人关键零部件-末端执行器-具有快换功能的夹持器	holder	Y
411	机器人共性关键技术-工业机器人关键技术-高性能工业机器人工业设计	industrial design	Y
412	机器人共性关键技术-工业机器人关键技术-运动控制	motion control	Y
413	机器人共性关键技术-工业机器人关键技术-精确参数辨识补偿	parameter identification	Y
414	机器人共性关键技术-工业机器人关键技术-协同作业与调度	collaboration and scheduling	Y
415	机器人共性关键技术-工业机器人关键技术-示教/编程	teach/program	Y
416	机器人共性关键技术-服务机器人关键技术-人机协同与安全	man-machine cooperation and security	Y
417	机器人共性关键技术-服务机器人关键技术-产品创意与性能优化设计	product creativity and performance optimization	Y
418	机器人共性关键技术-服务机器人关键技术-模块化/标准化体系结构设计	architecture design	Y
419	机器人共性关键技术-服务机器人关键技术-信息技术融合	technological convergence of information	Y
420	机器人共性关键技术-服务机器人关键技术-影像定位与导航	positioning and navigation	Y
421	机器人共性关键技术-服务机器人关键技术-生	myogenic	Y

No.	Content	Keyword	Included
	肌电感知与融合	electrical perception and fusion	
422	机器人共性关键技术-新一代机器人技术-人工智能	artificial intelligence	Y
423	机器人共性关键技术-新一代机器人技术-机器人深度学习	deep learning	Y
424	机器人共性关键技术-新一代机器人技术-机器人通用控制软件平台	control software platform	Y
425	机器人共性关键技术-新一代机器人技术-人机共存	man-machine symbiosis	Y
426	机器人共性关键技术-新一代机器人技术-安全控制	security control	Y
427	机器人共性关键技术-新一代机器人技术-高集成一体化关节	joints	Y
428	机器人共性关键技术-新一代机器人技术-灵巧手	dexterous hand	Y
429	机器人产业标准-机器人用RV减速机通用技术条件	RV reducer	Y
430	机器人产业标准-机器人整机电磁兼容技术要求和试验方法	electromagnetic compatibility	Y
431	机器人产业标准-个人护理机器人安全要求	personal care safety	Y
432	机器人产业标准-工业机器人编程和操作图形用户接口	industrial robot programming	Y
433	机器人产业标准-设计平台标准和喷涂机器人系统应用规范	spraying	Y
Plan 5: 关于推进工业机器人产业发展的指导意见(2013)			
434	机器人-工业机器人系统集成技术	system integration	Y
435	机器人-主机设计技术	host design	Y
436	机器人-关键零部件制造技术-伺服电机	servo motor	Y
437	机器人-关键零部件制造技术-精密减速器	precision reducer	Y
438	机器人-关键零部件制造技术-伺服驱动器	servo driver	Y
439	机器人-关键零部件制造技术-末端执行器、传感器	end effector, sensor	Y
Plan 6: 服务机器人科技发展“十二五”专项规划(2012)			
440	服务机器人集成技术-原型样机集成-关键零部件	key components	Y
441	服务机器人集成技术-原型样机集成-可靠性	reliability	Y

No.	Content	Keyword	Included
442	服务机器人-设计制造技术-产品设计	product design	Y
443	服务机器人-设计制造技术-材料与工艺技术	materials and process	Y
444	服务机器人-设计制造技术-系统集成水平	system integration level	Y
445	服务机器人-机器人机构学	mechanism	Y
446	服务机器人-动力学	dynamics	Y
447	服务机器人-环境适应技术	environmental adaptation	Y
448	服务机器人-关键部件-驱动器	driver	Y
449	服务机器人-关键部件-电机	motor	Y
450	服务机器人-关键部件-减速器	reducer	Y
451	服务机器人-产业化关键技术-产品创意与性能优化设计技术	product creation and performance optimization	Y
452	服务机器人-产业化关键技术-核心零部件制造技术	core components manufacturing	Y
453	服务机器人-产业化关键技术-高功率密度能源动力技术	energy power	Y
454	服务机器人-产业化关键技术-信息识别与宜人化人机交互技术	information identification and pleasant human-computer interaction	Y
455	服务机器人-产业化关键技术-人机共存安全技术	human computer coexistence security	Y
456	服务机器人-产业化关键技术-系统集成与应用技术	integration and application test	Y
457	服务机器人-产业化关键技术-性能测试规范与维护技术	specification and maintenance technology	Y
458	高端仿生技术-仿人形机器人	humanoid	Y
459	高端仿生技术-高负载高稳定高速机动仿生骡子	bionic mules	Y
460	高端仿生技术-适应多环境的自变形模块化机器人	self-deforming modular	Y

No.	Content	Keyword	Included
461	微纳系统技术-介入人体或血管的微纳米机器人	micro-nano	Y
462	微纳系统技术-脑生肌电认知与智能假肢控制技术	intelligent prosthetics module	Y
463	模块标准化平台技术-模块标准化体系结构	standardized architecture	Y
464	模块标准化平台技术-开源机器人控制与软件系统	open-source robot control and software system	Y
465	模块标准化平台技术-模块化互换性功能部件（传感器、驱动器、控制器等）	modular interchangeable functional unit	Y
466	模块标准化平台技术-接口协议	Interface Protocol	Y
Plan 7: 科技发展新态势与面向 2020 年的战略选择 (2013)			
467	智能制造-人-机共融智能制造	man-machine integration and intelligent manufacturing	N
Plan 8: 中科院 135 发展规划纲要-科技创新 2030—重大项目 (2016)			
468	智能制造和机器人	intelligent manufacturing and robotics	N
469	人工肌肉	artificial muscle	Y

Robustness Checks: On the Characterizing Indicators

We select two technologies from the top significant 150 technologies, namely, *Industrial Robot Programming* and *Artificial Muscles*. We also acquire their historical search data (spans from 2000 to 2016) from *Google* to test the robustness of the proposed indicators. The historical trends of the values of the four indicators of these technologies are calculated and plotted in Fig. S1.

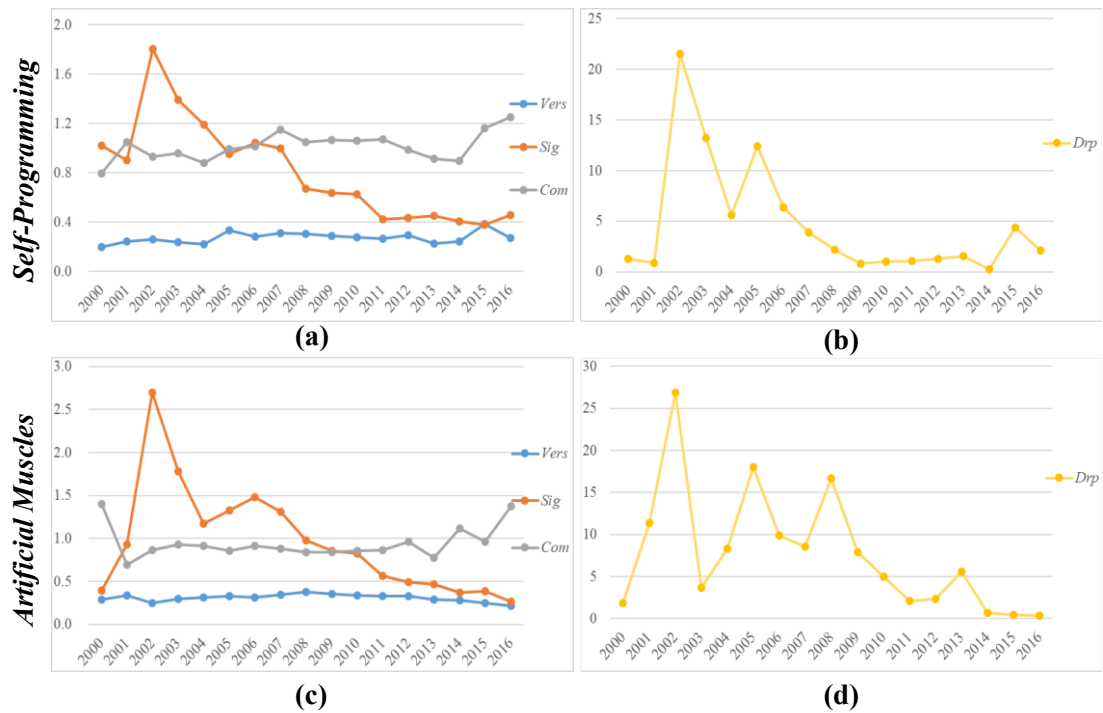


Fig. S1. Historical trends of the four indicators of the two selected technologies, i.e., *Industrial Robot Programming* and *Artificial Muscles*.

Figs. S1 (a) and (b) show that the values of the versatility indicator remain low during the studied period of 2000 to 2016, which indicates that *Industrial Robot Programming* can be considered a specialized technology. The technology of *Industrial Robot Programming*, or referred to as *Self-Programming* or *Automatic Programming* in several cases, is essentially based on domain-specific knowledge [1]. Thus, its research and applications are highly specialized. The applications of this technology are mostly concentrated at expression generation [2] and classification [3], [4]. However, several natural language processing technologies can also be applied to perform these tasks. For example, term frequency–inverse document frequency is a frequently used technique for text classification. The limited but non-exclusive potential application scenarios of the technology are consistent with the low values of the commerciality indicator; the value was generally less than 1.2 during the studied period. The values of the significance indicator are correlated with the values of the disruptiveness indicator, and they show a general descending trend. The booming of *Industrial Robot Programming* at the beginning of 21st century could probably be attributed to the introduction of declarative languages [5] and higher order logic [6].

The recent spike in the values of the significance, commerciality, and disruptiveness indicators is possibly triggered by the introduction of deep learning [7].

The historical values of the versatility indicator of *Artificial Muscles* are again quite low during the entire studied period, which means that the technology tends to be highly specialized, as shown in Figs. S1 (c) and (d). The development of *Artificial Muscles* was in stagnation for a quite long period without suitable materials that are lightweight and controllable; the advent of electroactive polymers boosts this research nearly instantly [8]. Consequently, the values of the significance and disruptiveness indicators increased sharply at the beginning of this century, as shown in Figs. S1 (c) and (d). The applications of *Artificial Muscles* that are based on electroactive polymers are expanding [9]–[12]; this pattern is consistent with the increasing commerciality values. However, the significance and disruptiveness indicators show descending trends as the technology received less and less attention due to the multiple weaknesses of the materials like short lifespan, high economic cost, and energy consumption [13].

Robustness Checks: On the Observed Feature Distributions

We also demonstrate that the innovations exhibit similar distributions in altered analytical spaces for checking the robustness of the observed feature distributions. In other words, the outcomes of the measurement should be proven to be constant. To this end, we took a simplified route: we reduce the quantity of the 2D analytical subspaces from 48 (6×8) to 35 (5×7), 24 (4×6), and 15 (3×5); then, we examine the distributions of the 452 intelligent robotics technologies. We calculate the values of the four indicators of the total of 452 technologies based on the search results retrieved from *Google*. Thereafter, we plot the results in descending orders in Fig. S2.

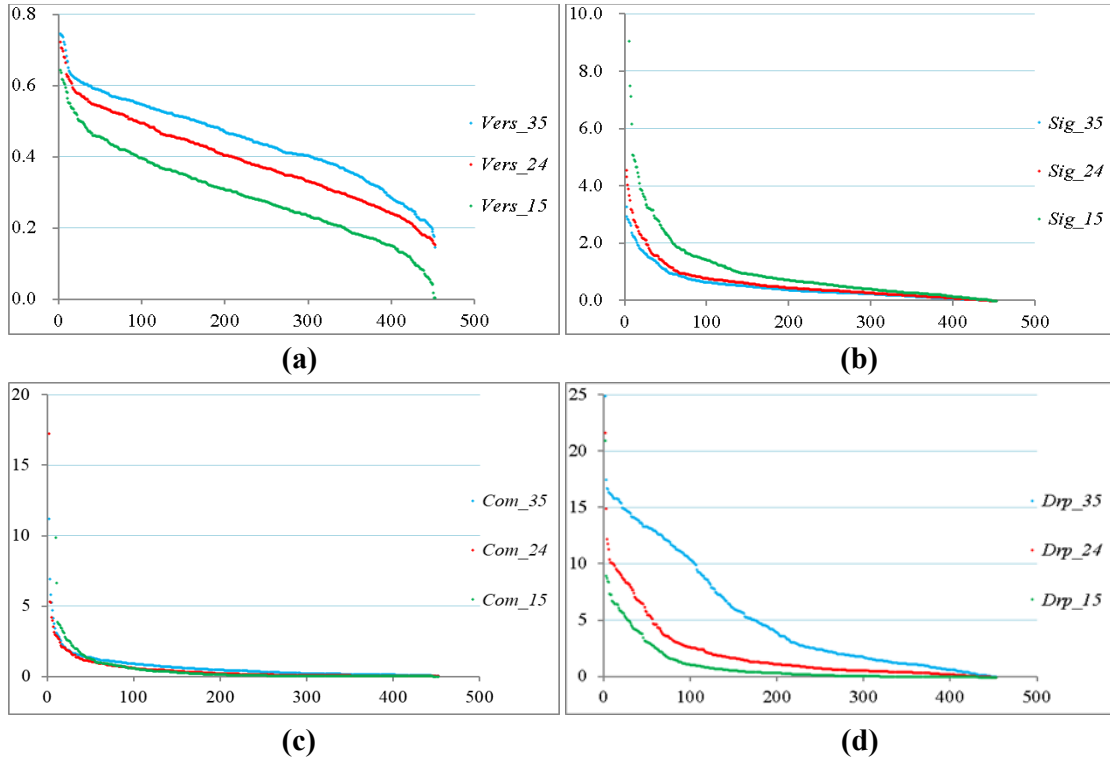


Fig. S2. Values of the four indexes of the 452 selected intelligent robotic technologies, and they are plotted in descending orders: (a) *Vers* values; (b) *Sig* values; (c) *Com* values; (d) *Drp* values.

Fig. S2 shows that the distributions of the defined indicators of the 452 technologies are nearly identical to those observed in the previous plots (Figs. 3, 4, 5, and 6). The distortion in the Drp_k values also persists. The decreasing quantity of the 2D analytical subspaces imparts no observable impacts on the outcomes of the measurement; the findings are highly constant. Therefore, the robustness of the observed distributions is proven, and the pattern of such distributions could pervasively exist in any technological domain.

Methodological Comparison

To demonstrate the distinctiveness of our online big data-based method from conventional technological assessment approaches, we have plotted the *S-curve* and *Gartner Hype Cycle* for the technologies of *Industrial Robot Programming* and *Artificial Muscles*, in Fig. S3. Following Ernst [14], the *S-curves* are plotted based on the patent application data (spans from 2000 to 2016) from the IncoPat database (<https://www.incopat.com/>). We employ the method proposed by Sasaki [15] to plot the *Gartner Hype Cycles*, in which the news reports from the LexisNexis database are used to form the “Hype Stage” (red-dot lines in Fig. S3 [b] and [d]) [16] and the patent application data from the IncoPat database is used to form the “Implementation Stage” (red-dot lines in Fig. S3 [b] and [d]) [14], [17]. The final *Gartner Hype Cycles* are denoted in the blue curves in Fig. S3 (b) and (d). It worth mentioning that according to Jun [17], [18], news reports can validly represent the expectations on certain technology, which from full of hopes to disappointments.

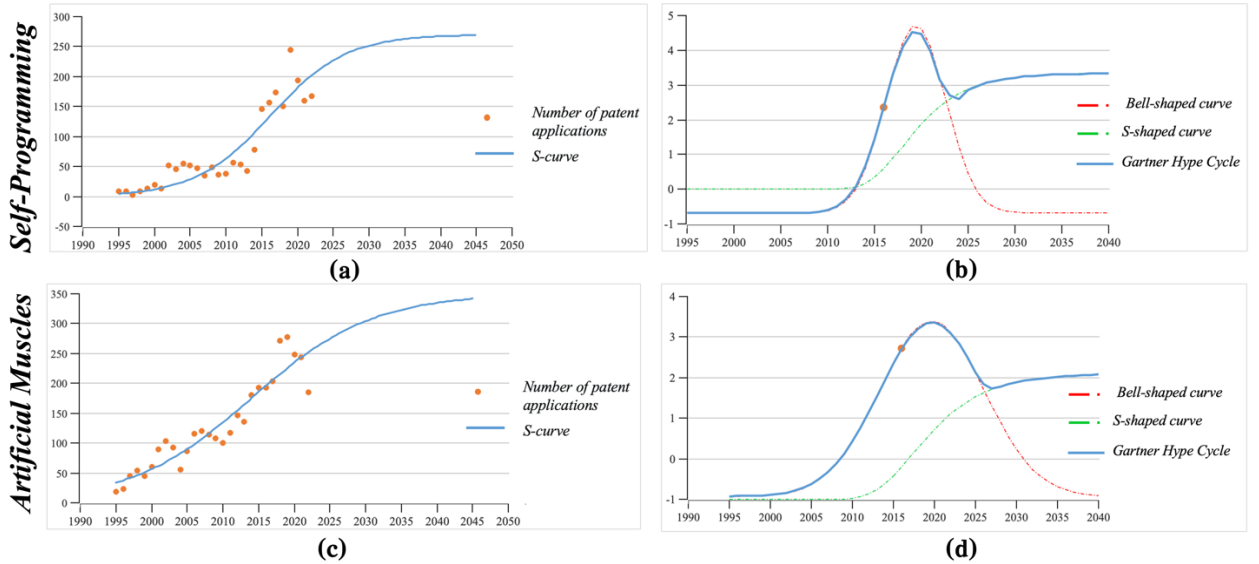


Fig. S3. Developmental trends of the two selected technologies, i.e., *Industrial Robot Programming* and *Artificial Muscles*, are plotted using *S-curve* and *Garner Hype Cycle*. (a) *S-curve* of *Self-Programming*; (b) *Garner Hype Cycle* of *Self-Programming*; (c) *S-curve* of *Artificial Muscles*; (d) *Garner Hype Cycle* of *Artificial Muscles*.

Fig. S3 (a) shows that the maturity of *Industrial Robot Programming* was increasing dramatically during the period of 2000 and 2016, while our approach and the above literature analysis contradict the finding; the commercial prospect of this technology has decreased. The *Garner Hype Cycle* (see Fig. S3 [b]) suggests that the development of *Industrial Robot Programming* was slow before 2010. Yet, this observation again contradicts the findings from our approach and literature analysis; the technology enjoyed a rapid development due to the introduction of declarative languages [5] and higher order logic [6], and the technology’s high significance values (see Fig. S1 [a]) are compatible with the outcome of the literature analysis.

The *S-curve* of *Artificial Muscles* (see Fig. S3 [c]) indicates that this technology had a turning point after 2014. However, the aforementioned literature analysis shows that with the emergence of electroactive polymers in the beginning of 21st century, this technology experienced a dramatic progress [8]. During 2000 to 2008, the values of commerciality and disruptiveness indicators of *Artificial Muscles* are greater than the averages of the 150 key technologies, indicating that the technology had attracted significant attention in the period. Yet again, the pattern of the *Artificial Muscles*' *S-curve* is not conformed with the literature analysis and the findings of our method.

The *Gartner Hype Cycle* of *Artificial Muscles* (see Fig. S3 [d]) shows that the technology was continuously attracting public attention during the period of 2000 to 2016. However, the observations derived from our approach indicate otherwise; the values of the significance and disruptiveness indicators of this technology are generally decreasing, only the values of the commerciality indicator are increasing around the year of 2016. The literature analysis supports the outcomes of our approach; the slowed development of *Artificial Muscles* is observed in the literature, and this can be possibly attributed to the absence of novel materials other than electroactive polymers.

To conclude, though *S-curve* and *Gartner Hype Cycle* have been extensively applied to technological assessments, their performance is proved to be inferior to our method, and is always deviated from the reality.

References

- [1] D. R. Barstow, "c," *IEEE Transactions on Software Engineering*, vol. 11, no. 11, pp. 1321-1336, 1985.
- [2] D. Rivero, J. R. Rabunal, J. Dorado, and A. Pazos, "Time series forecast with anticipation using genetic programming," *Computational intelligence and bioinspired systems*, 8th international work-conference on artificial neural networks, Springer, Berlin, Heidelberg, 2005.
- [3] P. Espejo, S. Ventura, and F. Herrera, "A survey on the application of genetic programming to classification," *IEEE Transactions on Systems Man and Cybernetics Part C (Applications and Reviews)*, vol. 40, no. 2, pp. 121-144, 2010.
- [4] L. Guo *et al.*, "Automatic feature extraction using genetic programming: An application to epileptic EEG classification," *Expert Systems with Applications*, vol. 38, no. 8, pp. 10425-10436, 2011.
- [5] F. Bry and S. Schaffert, "Towards a declarative query and transformation language for XML and semistructured data: Simulation unification," *International Conference on Logic Programming*. Springer, Berlin, Heidelberg, 2002.
- [6] M. Hanus and C. Prehofer, "Higher-order narrowing with definitional trees," *J. Funct. Program.*, vol. 9, no. 1, pp. 33-75, 1999.
- [7] B. M. Lake, R. Salakhutdinov, and J. B. Tenenbaum, "Human-level concept learning through probabilistic program induction," *Science*, vol. 350, no. 6266, pp. 1332-1338, 2015.
- [8] Y. Bar-Cohen, "Electroactive polymers as artificial muscles-capabilities, potentials and challenges," *Handbook on Biomimetics*, 2000.
- [9] J. W. Paquette and K. J. Kim, "Ionomeric electroactive polymer artificial muscle for naval applications," *IEEE Journal of Oceanic Engineering*, vol. 29, no. 3, pp. 729-737, 2004.
- [10] F. Carpi, R. D. Kornbluh, P. Sommerlarsen, and G. Alici, "Electroactive polymer actuators as artificial muscles: Are they ready for bioinspired applications," *Bioinspiration Biomimetics*, vol. 6, no. 4, no. 045006, 2011.
- [11] R. F. Shepherd *et al.*, "Multigait soft robot", *Proceedings of the National Academy of Sciences of the United States of America*, vol. 108, no. 51, pp. 20400-20403, 2011.
- [12] S. Chiba *et al.*, "Consistent ocean wave energy harvesting using electroactive polymer (dielectric elastomer) artificial muscle generators," *Applied Energy*, vol. 104, pp. 497-502, 2013.
- [13] C. S. Haines *et al.*, "New twist on artificial muscles," *Proceedings of the National Academy of Sciences of the United States of America*, vol. 113, no. 42, pp. 11709-11716, 2016.
- [14] H. Ernst, "The use of patent data for technological forecasting: The diffusion of CNC-technology in the machine tool industry", *Small Business Economics*, vol. 9, no. 4, pp. 361-381, 1997.
- [15] H. Sasaki, "Simulating Hype Cycle Curves with mathematical functions: Some examples of high-tech trends in Japan", *International Journal of Information Management Technology*, vol. 7, pp. 1-12, 2015.

- [16] H. Jarvenpaa and S. J. Makinen, "Empirically detecting the Hype Cycle with the life cycle indicators: An exploratory analysis of three technologies", in *2008 IEEE International Conference on Industrial Engineering and Engineering Management*, pp. 12-16, 2008.
- [17] S.-P. Jun, "An empirical study of users' hype cycle based on search traffic: the case study on hybrid cars", *Scientometrics*, vol. 91, no. 1, pp. 81-99, 2011.
- [18] S.-P. Jun, "A comparative study of hype cycles among actors within the socio-technical system: With a focus on the case study of hybrid cars", *Technological Forecasting and Social Change*, vol. 79, no. 8, pp. 1413-1430, 2012.