**UNITED STATES DEPARTMENT OF COMMERCE**
**National Institute of Standards and Technology**
Gaithersburg, Maryland 20899-

March 26, 2012

**MEMORANDUM FOR** Howard Harary
Deputy Director, Manufacturing
Engineering Laboratory

**From:** Al Wavering
Chief, Intelligent Systems Division
Engineering Laboratory

**Subject**: Recommendation to fund grant from Regents of the University of California titled, "*Grasping and Simulation for Next-Generation Manufacturing Robots*"

In response to a solicitation in the Federal Register through the Measurement Science and Engineering Research Grants Program (Docket Number: 2012-MSE-01), the Intelligent Systems Division of the Engineering Laboratory has received a grant proposal from Regents of the University of California titled "*Grasping and Simulation for Next-Generation Manufacturing Robots*". This grant proposal addresses our need to help promote efforts in simulations for measuring and modeling next-generation manufacturing environments.

A panel of three technical experts within the division evaluated the grant proposal. Their attached reviews had an average score of 91.3/100. The approach described appears to address the relevant technical issues involved in the development of this knowledge model. The principal investigator (PI) has worked with NIST staff for several years and has a great deal of experience with simulation and is suitably qualified to perform the work described in the proposal.

Therefore, I recommend that we fully fund the work contingent upon the availability of funds, for the requested amount ($584,197). The Intelligent Systems Division has sufficient funds to cover the costs in our project cost center (735-2006-000).

The reviewers and scores for the proposal were:

| | Score |
|---|---|
| Joe Falco, Mechanical Engineer, Intelligent Systems Division | 90/100 |
| Tom Kramer, Mechanical Engineer, Intelligent Systems Division | 93/100 |
| Jeremy Marvel, Guest Researcher, Intelligent Systems Division | 91/100 |
| **Average** | **91.3/100** |

Comments from the review panel are summarized as follows:

**Technical Quality:** The technical quality of the proposed work may be expected to be excellent. Two reviewers suggest awarding the grant as a cooperative agreement based on the need for constant interaction and collaboration with NIST staff.

**Impact:** This work will compliment work currently in progress at NIST with grasping and simulation. The human avatar will undoubtedly help promote NIST's efforts in simulation for measuring and modeling next-generation manufacturing environments, and should aid in expanding the utilization of USARSim within the field of robotics. The expertise in both simulation and grasping will have significant impact on the Dexterous Manipulation for Automation Systems project (Grasp Performance Metrics) and the Intelligent Planning and Modeling for Autonomous Systems project within the Next Generation Robotics and Automation project.

**Staff Capability:** The staff show significant capability in USARSim simulation development work and grasping based on published papers. The principal investigator has worked closely with NIST staff for several years. He has a great deal of experience with simulation. There is little doubt that the staff and institution have the necessary experience for the proposed work.

**Budget Match:** The budget seems appropriate for the level of work in the proposal. The proposed work in grasping should be expanded to justify the proposed budget, but this can easily be accomplished based on the staffing capabilities. Given ISD's input, this reviewer is comfortable with the budget for the effort required.

Attached, please find a copy of the proposal and the score sheets from each reviewer.

**UNITED STATES DEPARTMENT OF COMMERCE**
**National Institute of Standards and Technology**
Gaithersburg, Maryland 20899-

Date: March 12, 2012

Memorandum for NIST Grants Officer

FROM: Albert Wavering
Chief, Division 735
Selecting Official

SUBJECT: Selection Recommendation under FFO 2012-NIST-MSE-01 for proposal/application reviewed from The Regents of the University of California Corporation dated February 10, 2012

**Certification of Review and Selection Process:**
In accordance with the procedures set forth in the subject FFO, an individual competition was conducted for the attached proposal reviewed on 03-11-2012. I hereby certify that the process as stated here and in the "Review and Selection Process" section of the FFO was followed.

All proposals received in response to the FFO for the Engineering Laboratory Grants and Cooperative Agreements Program are reviewed as received on a rolling basis to determine whether or not they are eligible, complete, and responsive to the FFO and are compatible and relevant to the objectives of the Engineering Laboratory Grants and Cooperative Research Grant Program, as described in the Program Description (Section I.3 of the FFO). Proposals determined to be ineligible, incomplete, and/or non-responsive based on the FFO may be eliminated from further review. Additionally, if it is determined that sufficient funding is not available to consider proposals in the technical area of the proposal, the proposal will not be reviewed for technical merit, and the proposer will be promptly notified of the unavailability of funds for their proposal. The Engineering Laboratory Grants and Cooperative Research Program will post a notice on its Web site when funds are exhausted for the fiscal year.

At least three (3) independent, objective individuals knowledgeable about the particular scientific area described in the proposal will conduct a technical review of each proposal, based on the evaluation criteria (Section V.1.c. of the FFO). If non-federal reviewers are used, the reviewers may discuss the proposals with each other, but scores will be determined on an individual basis, not as a consensus.

The Selecting Official, who is the EL Director, EL Deputy Director, or appropriate EL Division Chief will make final proposal selections, taking into consideration the results of the reviewers' evaluations, relevance to the objectives described in the EL Grant Program Description (Section I.3. of the FFO), and the availability of funds. The selection of proposals by the Selecting Official is final.

NIST reserves the right to negotiate the budget costs with the proposers that have been selected to receive awards, which may include requesting that the proposer remove certain costs. Additionally, NIST may request that the proposer modify objectives or work plans and provide supplemental information required by the agency prior to award. NIST also reserves the right to reject a proposal where information is uncovered that raises a reasonable doubt as to the responsibility of the proposer. NIST may select part, some, all, or none of the proposals. The final approval of selected proposals and issuance of awards will be by the NIST Grants Officer. The award decisions of the Grants Officer are final.

**Evaluation Criteria:**
The evaluation criteria used by the independent reviewers was:

(1) Technical Quality of the Research. The rationality, innovation and imagination of the proposal, and the fit to NIST's in-house EL programs. (0 – 35 points)

(2) Potential Impact of the Results. The potential impact and the likelihood of the technical application of the results. (0 – 25 points)

(3) Staff and Institution Capability to Perform the Work. The quality of the facilities and experience of the staff to assess the likelihood of achieving the objective of the proposal. (0 – 20 points)

(4) Match of Budget to Proposed Work. Assessment of the budget against the proposed work to ascertain the reasonableness of the request. (0 – 20 points)

**Individual Reviews and Instructions:**
Attached hereto are copies of the individual reviews and any instructions that were provided to the reviewers.

**List of Previously Approved Proposals:**
The priority score for this proposal is consistent with the priority scoring levels for proposals this program has previously recommended for funding as noted below.

*(a)* Southwest Research Institute (SWRI), *"Development of Standards Test Methods to Evaluate Performance of Emergency Response Robots," $107,606.00-funded. Scores 100, 99, and 93.*

*(b)* Texas Engineering Extension Service (TEEX), *"Robotics Exercise to Conduct Research into Performance Measures Applied to Realistic Urban Search and Rescue Training Scenarios," $46,565.00-funded. Scores 100, 99, and 95.*

*(c)* University of Maryland, Baltimore County, *" Information Streaming of the NIST Disaster and Failure Events Database for Extreme Events," $81,619.00-1st year funded. Scores 98, 95 and 95.*

**Technical Evaluation/Applicant Selection:**
In selecting applications, I took into consideration the proposers background and knowledge of USARSim simulation development work and grasping. I hereby recommend funding the reviewed proposal, contingent upon the availability of funds, for The Regents of the University of California, *Grasping and Simulation for Next-Generation Manufacturing Robots*, with an average score of 91.3, and an estimated cost of $584,197.

**Cost Evaluation:**
The proposed budget has been reviewed for relevancy and realism to the program described in the proposal. All proposal costs, [except those noted below, if any] are found to be fair and reasonable.

**Level of Federal Involvement [Substantial or Non-Substantial]:** Substantial

**Statement of Benefits:**

1. Benefit to NIST: This research will further the current research in automated manufacturing.

2. Benefit to the Recipient: The Principal Investigator and staff will be able to work collaboratively with NIST to further research in next-generation manufacturing.

3. Benefit to the General Public: The benefit to the general public is the advancement of research in next-generation manufacturing and promote NIST's efforts in simulation for measuring and modeling next-generation manufacturing environments.

**Federal Program Officer:**

The Federal Program Officer (FPO) Stephen Balakirsky, who is responsible for monitoring the technical and scientific progress of the award, and has been assigned in the Grants Management Information System (GMIS), has the requisite knowledge and skills to monitor the award and is a direct hire employee of the U.S. Government.

Questions related to this selection can be addressed to me at extension 3461.

**Engineering Laboratory**
**Unsolicited Grant Proposal Technical Review** (Proposal #2012-735-2004)

**Date:** 2/15/2012 **Reviewer Name/Signature:** Thomas R. Kramer

**Proposal Title:** Grasping and Simulation for Next-Generation Manufacturing Robots

**Principal Investigator(s) and Institution:** Regents of the University of California – Prof. Carpin

| | |
|---|---|
| **Technical Quality of the research (0-35):** | **Your Score:** 33 |
| **Potential Impact of the results (0-25):** | **Your Score:** 23 |
| **Staff and Institution Capability to do the work (0-20):** | **Your Score:** 19 |
| **Match of Budget to proposed work (0-20):** | **Your Score:** 18 |
| **TOTAL SCORE (0-100):** | 93 |

**Rating Justifications:**

**Technical Quality:**

The technical quality of the proposed work may be expected to be excellent

**Impact:**

This work will complement work in progress at NIST with grasping and simulation.

**Staff Capability:**

The principal investigator has worked closely with NIST staff for several years. He has a great deal of experience with simulation.

**Budget Match:** The budget match is good.

**Engineering Laboratory**
**Unsolicited Grant Proposal Technical Review (Proposal #2012-735-2004)**

**Date: 2/15/2012** **Reviewer Name/Signature:** Joe Falco

**Proposal Title:** Grasping and Simulation for Next-Generation Manufacturing Robots

**Principal Investigator(s) and Institution:** Regents of the University of California – Prof. Carpin

| | |
|---|---|
| **Technical Quality of the research (0-35):** | **Your Score:** 29 |
| **Potential Impact of the results (0-25):** | **Your Score:** 24 |
| **Staff and Institution Capability to do the work (0-20):** | **Your Score:** 20 |
| **Match of Budget to proposed work (0-20):** | **Your Score:** 17 |
| **TOTAL SCORE (0-100):** | 90 |

**Rating Justifications:**

**Technical Quality:** See Attached

**Impact:** See Attached

**Staff Capability:** See Attached

**Budget Match:** See Attached

**Proposal #2012-735-2004 (Falco)**

**Technical Quality:** Generation of a survey on grasping taking into account contemporary developments and the latest in technology would be very beneficial to NIST and the grasping research community as a whole I feel that this work should be a subset of a one year effort in grasping and given the staff capabilities that additional contributions can be made in grasp algorithms, grasp performance metrics and manipulation. NIST is in the process of procuring an advanced robotic hand to support efforts to identify performance metrics and tests for advanced robotic hands and associated grasp algorithms. I suggest that this grant be categorized as a cooperative agreement so that NIST and UCM can identify and coordinate areas of interest as efforts progress. - 29

**Impact:** The expertise in both simulation and grasping will have significant impact on the Dexterous Manipulation for Automation Systems Project (Grasp Performance Metrics) and the Intelligent Planning and Modeling for Autonomous Systems Project within the Next Generation Robotics and Automation Project (USARSim is a simulation environment supporting this project work). - 24

**Staff Capability:** Staff shows significant capability in USARSim simulation development work and grasping based on published papers (references provided) - 20

**Budget Match:** The proposed work in grasping should be expanded to justify the proposed budget. This can be very easily accomplished based on the staffing capabilities. See Technical Quality - 17

**Engineering Laboratory**
**Unsolicited Grant Proposal Technical Review (Proposal #2012-735-2004)**

**Date:** 2/15/2012 **Reviewer Name/Signature:** Jeremy A. Marvel

**Proposal Title:** Grasping and Simulation for Next-Generation Manufacturing Robots

**Principal Investigator(s) and Institution:** Regents of the University of California – Prof. Carpin

| | |
|---|---|
| **Technical Quality of the research (0-35):** | **Your Score:** 30 |
| **Potential Impact of the results (0-25):** | **Your Score:** 23 |
| **Staff and Institution Capability to do the work (0-20):** | **Your Score:** 20 |
| **Match of Budget to proposed work (0-20):** | **Your Score:** 18 |
| | **TOTAL SCORE (0-100):** 91 |

**Rating Justifications:**

**Technical Quality:**

In its current form, the technical quality of the proposed research is not quite sufficient for funding 2 1/4 researchers for one year. However, there is clear potential, and I suggest the grant be awarded as a collaborative agreement such that NIST can provide ongoing input to steer the research efforts. In particular, the proposed grasping primer does not capture the performance metrics and evaluative test procedures for either dexterous manipulation or the manufacturing capacity of grasping, both of which are pivotal to next-generation manufacturing. The scores for "Impact" and "Budget" are reflective of this collaborative agreement contingency.

**Impact:**

The human avatar will undoubtedly help promote NIST's efforts in simulations for measuring and modeling next-generation manufacturing environments, and should aid in expanding the utilization of USARSim within the field of robotics. Given our guidance, the grasping/manipulation primer will aid NIST's metrological and standards efforts with regards to dexterous manipulation and agile manufacturing.

**Staff Capability:**

There is little doubt that the staff and institution have the necessary experience for the proposed work. Though the capabilities of the two graduate students are unknown, their positions are sufficient reason to believe they can produce the expected deliverables.

**Budget Match:**

Given our input, I am comfortable with the budget for the effort required.

OMB Number: 4040-0004
Expiration Date: 01/31/2009

## Application for Federal Assistance SF-424

Version 02

| * 1. Type of Submission: | * 2. Type of Application: | * If Revision, select appropriate letter(s): |
|---|---|---|
| ☐ Preapplication | ☒ New | |
| ☒ Application | ☐ Continuation | * Other (Specify) |
| ☐ Changed/Corrected Application | ☐ Revision | |

| * 3. Date Received: | 4. Applicant Identifier: |
|---|---|
| 02/10/2012 | |

| 5a. Federal Entity Identifier: | * 5b. Federal Award Identifier: |
|---|---|
| | |

**State Use Only:**

| 6. Date Received by State: | 7. State Application Identifier: |
|---|---|
| | |

**8. APPLICANT INFORMATION:**

| | |
|---|---|
| * a. Legal Name: | The Regents of the University of California |

| * b. Employer/Taxpayer Identification Number (EIN/TIN): | * c. Organizational DUNS: |
|---|---|
| 27-0093858 | 113645084 |

**d. Address:**

| | |
|---|---|
| * Street1: | 5200 N. Lake Road |
| Street2: | |
| * City: | Merced |
| County: | Merced |
| * State: | CA: California |
| Province: | |
| * Country: | USA: UNITED STATES |
| * Zip / Postal Code: | 95343-5705 |

**e. Organizational Unit:**

| Department Name: | Division Name: |
|---|---|
| N/A | School of Engineering |

**f. Name and contact information of person to be contacted on matters involving this application:**

| | | | |
|---|---|---|---|
| Prefix: | Mrs. | * First Name: | Thea |
| Middle Name: | | | |
| * Last Name: | Vicari | | |
| Suffix: | | | |

| | |
|---|---|
| Title: | Director of Sponsored Projects |
| Organizational Affiliation: | University of California, Merced |

| | | | |
|---|---|---|---|
| * Telephone Number: | 209-228-4318 | Fax Number: | 209-228-6906 |
| * Email: | spo@ucmerced.edu | | |

OMB Number: 4040-0004
Expiration Date: 01/31/2009

## Application for Federal Assistance SF-424

Version 02

**9. Type of Applicant 1: Select Applicant Type:**

H: Public/State Controlled Institution of Higher Education

Type of Applicant 2: Select Applicant Type:

S: Hispanic-serving Institution

Type of Applicant 3: Select Applicant Type:

* Other (specify):

*** 10. Name of Federal Agency:**

National Institute of Standards and Technology

**11. Catalog of Federal Domestic Assistance Number:**

11.609

CFDA Title:

Measurement and Engineering Research and Standards

*** 12. Funding Opportunity Number:**

2012-NIST-MSE-01

* Title:

Measurement Science and Engineering (MSE) Research Grant Programs

**13. Competition Identification Number:**

2012-NIST-MSE-01

Title:

**14. Areas Affected by Project (Cities, Counties, States, etc.):**

Manufacturing, Dexterous Manipulation, Intelligent Planning, *High-Fidelity Simulation*

*** 15. Descriptive Title of Applicant's Project:**

Grasping and Simulation for Next-Generation Manufacturing Robots

Attach supporting documents as specified in agency instructions.

Add Attachments | Delete Attachments | View Attachments

OMB Number: 4040-0004
Expiration Date: 01/31/2009

## Application for Federal Assistance SF-424

Version 02

**16. Congressional Districts Of:**

* a. Applicant: CA-018 * b. Program/Project: CA-018

Attach an additional list of Program/Project Congressional Districts if needed.

Add Attachment | Delete Attachment | View Attachment

**17. Proposed Project:**

* a. Start Date: 08/15/2012 * b. End Date: 08/14/2015

**18. Estimated Funding ($):**

| | |
|---|---|
| * a. Federal | 584,197.00 |
| * b. Applicant | 0.00 |
| * c. State | 0.00 |
| * d. Local | 0.00 |
| * e. Other | 0.00 |
| * f. Program Income | 0.00 |
| * g. TOTAL | 584,197.00 |

*** 19. Is Application Subject to Review By State Under Executive Order 12372 Process?**

☐ a. This application was made available to the State under the Executive Order 12372 Process for review on .

☐ b. Program is subject to E.O. 12372 but has not been selected by the State for review.

☒ c. Program is not covered by E.O. 12372.

*** 20. Is the Applicant Delinquent On Any Federal Debt? (If "Yes", provide explanation.)**

☐ Yes ☒ No

**21. *By signing this application, I certify (1) to the statements contained in the list of certifications** and (2) that the statements herein are true, complete and accurate to the best of my knowledge. I also provide the required assurances** and agree to comply with any resulting terms if I accept an award. I am aware that any false, fictitious, or fraudulent statements or claims may subject me to criminal, civil, or administrative penalties. (U.S. Code, Title 218, Section 1001)**

☒ ** I AGREE

** The list of certifications and assurances, or an internet site where you may obtain this list, is contained in the announcement or agency specific instructions.

**Authorized Representative:**

Prefix: Mrs. * First Name: Thea

Middle Name:

* Last Name: Vicari

Suffix:

* Title: Director of Sponsored Projects

* Telephone Number: 209-228-4318 Fax Number: 209-228-6906

* Email: spo@ucmerced.edu

* Signature of Authorized Representative: Jennifer Teixeira * Date Signed: 02/10/2012

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Standard Form 424 (Revised 10/2005)
Prescribed by OMB Circular A-102

## Application for Federal Assistance SF-424

Version 02

*** Applicant Federal Debt Delinquency Explanation**

The following field should contain an explanation if the Applicant organization is delinquent on any Federal Debt. Maximum number of characters that can be entered is 4,000. Try and avoid extra spaces and carriage returns to maximize the availability of space.

# BUDGET INFORMATION - Non-Construction Programs

OMB Number: 4040-0006
Expiration Date: 06/30/2014

## SECTION A - BUDGET SUMMARY

| Grant Program Function or Activity (a) | Catalog of Federal Domestic Assistance Number (b) | Estimated Unobligated Funds | | New or Revised Budget | | |
|---|---|---|---|---|---|---|
| | | Federal (c) | Non-Federal (d) | Federal (e) | Non-Federal (f) | Total (g) |
| 1. Year 1 Funds | 11.609 | $ | $ | $ 199,352.00 | $ 0.00 | $ 199,352.00 |
| 2. Year 2 Funds (Optional) | 11.609 | | | 209,137.00 | 0.00 | 209,137.00 |
| 3. Year 3 Funds (Optional) | 11.609 | | | 175,708.00 | 0.00 | 175,708.00 |
| 4. | | | | | | |
| 5. Totals | | $ | $ | $ 584,197.00 | $ | $ 584,197.00 |

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Prescribed by OMB (Circular A -102) Page 1

## SECTION B - BUDGET CATEGORIES

| 6. Object Class Categories | GRANT PROGRAM, FUNCTION OR ACTIVITY (1) Year 1 Funds | (2) Year 2 Funds (Optional) | (3) Year 3 Funds (Optional) | (4) | Total (5) |
|---|---|---|---|---|---|
| a. Personnel | $ 78,259.00 | $ 80,607.00 | $ 83,025.00 | $ | $ 241,891.00 |
| b. Fringe Benefits | 4,203.00 | 4,328.00 | 4,459.00 | | 12,990.00 |
| c. Travel | 7,760.00 | 7,760.00 | 3,000.00 | | 18,520.00 |
| d. Equipment | | | | | |
| e. Supplies | | | | | |
| f. Contractual | | | | | |
| g. Construction | | | | | |
| h. Other | 59,508.00 | 65,459.00 | 35,458.00 | | 160,425.00 |
| i. Total Direct Charges (sum of 6a-6h) | 149,730.00 | 158,154.00 | 125,942.00 | | $ 433,826.00 |
| j. Indirect Charges | 49,622.00 | 50,983.00 | 49,766.00 | | $ 150,371.00 |
| k. TOTALS (sum of 6i and 6j) | $ 199,352.00 | $ 209,137.00 | $ 175,708.00 | $ | $ 584,197.00 |
| | | | | | |
| 7. Program Income | $ 0.00 | $ 0.00 | $ 0.00 | $ | $ |

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## SECTION C - NON-FEDERAL RESOURCES

| (a) Grant Program | (b) Applicant | (c) State | (d) Other Sources | (e)TOTALS |
|---|---|---|---|---|
| 8. | $ | $ | $ | $ |
| 9. | | | | |
| 10. | | | | |
| 11. | | | | |
| 12. TOTAL (sum of lines 8-11) | $ | $ | $ | $ |

## SECTION D - FORECASTED CASH NEEDS

| | Total for 1st Year | 1st Quarter | 2nd Quarter | 3rd Quarter | 4th Quarter |
|---|---|---|---|---|---|
| 13. Federal | $ 199,352.00 | $ 49,838.00 | $ 49,838.00 | $ 49,838.00 | $ 49,838.00 |
| 14. Non-Federal | $ | | | | |
| 15. TOTAL (sum of lines 13 and 14) | $ 199,352.00 | $ 49,838.00 | $ 49,838.00 | $ 49,838.00 | $ 49,838.00 |

## SECTION E - BUDGET ESTIMATES OF FEDERAL FUNDS NEEDED FOR BALANCE OF THE PROJECT

| (a) Grant Program | FUTURE FUNDING PERIODS (YEARS) (b)First | (c) Second | (d) Third | (e) Fourth |
|---|---|---|---|---|
| 16. Year 2 Funds (Optional) | $ | $ 209,137.00 | $ | $ |
| 17. Year 3 Funds (Optional) | | | 175,708.00 | |
| 18. | | | | |
| 19. | | | | |
| 20. TOTAL (sum of lines 16 - 19) | $ | $ 209,137.00 | $ 175,708.00 | $ |

## SECTION F - OTHER BUDGET INFORMATION

21. Direct Charges: $433,826

22. Indirect Charges: $150,371

23. Remarks:

OMB Number: 4040-0007
Expiration Date: 06/30/2014

## ASSURANCES - NON-CONSTRUCTION PROGRAMS



**PLEASE DO NOT RETURN YOUR COMPLETED FORM TO THE OFFICE OF MANAGEMENT AND BUDGET. SEND IT TO THE ADDRESS PROVIDED BY THE SPONSORING AGENCY.**

**NOTE:** Certain of these assurances may not be applicable to your project or program. If you have questions, please contact the awarding agency. Further, certain Federal awarding agencies may require applicants to certify to additional assurances. If such is the case, you will be notified.

As the duly authorized representative of the applicant, I certify that the applicant:

1. Has the legal authority to apply for Federal assistance and the institutional, managerial and financial capability (including funds sufficient to pay the non-Federal share of project cost) to ensure proper planning, management and completion of the project described in this application.

2. Will give the awarding agency, the Comptroller General of the United States and, if appropriate, the State, through any authorized representative, access to and the right to examine all records, books, papers, or documents related to the award; and will establish a proper accounting system in accordance with generally accepted accounting standards or agency directives.

3. Will establish safeguards to prohibit employees from using their positions for a purpose that constitutes or presents the appearance of personal or organizational conflict of interest, or personal gain.

4. Will initiate and complete the work within the applicable time frame after receipt of approval of the awarding agency.

5. Will comply with the Intergovernmental Personnel Act of 1970 (42 U.S.C. §§4728-4763) relating to prescribed standards for merit systems for programs funded under one of the 19 statutes or regulations specified in Appendix A of OPM's Standards for a Merit System of Personnel Administration (5 C.F.R. 900, Subpart F).

6. Will comply with all Federal statutes relating to nondiscrimination. These include but are not limited to: (a) Title VI of the Civil Rights Act of 1964 (P.L. 88-352) which prohibits discrimination on the basis of race, color or national origin; (b) Title IX of the Education Amendments of 1972, as amended (20 U.S.C.§§1681-1683, and 1685-1686), which prohibits discrimination on the basis of sex; (c) Section 504 of the Rehabilitation Act of 1973, as amended (29 U.S.C. §794), which prohibits discrimination on the basis of handicaps; (d) the Age Discrimination Act of 1975, as amended (42 U. S.C. §§6101-6107), which prohibits discrimination on the basis of age; (e) the Drug Abuse Office and Treatment Act of 1972 (P.L. 92-255), as amended, relating to nondiscrimination on the basis of drug abuse; (f) the Comprehensive Alcohol Abuse and Alcoholism Prevention, Treatment and Rehabilitation Act of 1970 (P.L. 91-616), as amended, relating to nondiscrimination on the basis of alcohol abuse or alcoholism; (g) §§523 and 527 of the Public Health Service Act of 1912 (42 U.S.C. §§290 dd-3 and 290 ee- 3), as amended, relating to confidentiality of alcohol and drug abuse patient records; (h) Title VIII of the Civil Rights Act of 1968 (42 U.S.C. §§3601 et seq.), as amended, relating to nondiscrimination in the sale, rental or financing of housing; (i) any other nondiscrimination provisions in the specific statute(s) under which application for Federal assistance is being made; and, (j) the requirements of any other nondiscrimination statute(s) which may apply to the application.

7. Will comply, or has already complied, with the requirements of Titles II and III of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (P.L. 91-646) which provide for fair and equitable treatment of persons displaced or whose property is acquired as a result of Federal or federally-assisted programs. These requirements apply to all interests in real property acquired for project purposes regardless of Federal participation in purchases.

8. Will comply, as applicable, with provisions of the Hatch Act (5 U.S.C. §§1501-1508 and 7324-7328) which limit the political activities of employees whose principal employment activities are funded in whole or in part with Federal funds.

9. Will comply, as applicable, with the provisions of the Davis-Bacon Act (40 U.S.C. §§276a to 276a-7), the Copeland Act (40 U.S.C. §276c and 18 U.S.C. §874), and the Contract Work Hours and Safety Standards Act (40 U.S.C. §§327-333), regarding labor standards for federally-assisted construction subagreements.

10. Will comply, if applicable, with flood insurance purchase requirements of Section 102(a) of the Flood Disaster Protection Act of 1973 (P.L. 93-234) which requires recipients in a special flood hazard area to participate in the program and to purchase flood insurance if the total cost of insurable construction and acquisition is $10,000 or more.

11. Will comply with environmental standards which may be prescribed pursuant to the following: (a) institution of environmental quality control measures under the National Environmental Policy Act of 1969 (P.L. 91-190) and Executive Order (EO) 11514; (b) notification of violating facilities pursuant to EO 11738; (c) protection of wetlands pursuant to EO 11990; (d) evaluation of flood hazards in floodplains in accordance with EO 11988; (e) assurance of project consistency with the approved State management program developed under the Coastal Zone Management Act of 1972 (16 U.S.C. §§1451 et seq.); (f) conformity of Federal actions to State (Clean Air) Implementation Plans under Section 176(c) of the Clean Air Act of 1955, as amended (42 U.S.C. §§7401 et seq.); (g) protection of underground sources of drinking water under the Safe Drinking Water Act of 1974, as amended (P.L. 93-523); and, (h) protection of endangered species under the Endangered Species Act of 1973, as amended (P.L. 93-205).

12. Will comply with the Wild and Scenic Rivers Act of 1968 (16 U.S.C. §§1271 et seq.) related to protecting components or potential components of the national wild and scenic rivers system.

13. Will assist the awarding agency in assuring compliance with Section 106 of the National Historic Preservation Act of 1966, as amended (16 U.S.C. §470), EO 11593 (identification and protection of historic properties), and the Archaeological and Historic Preservation Act of 1974 (16 U.S.C. §§469a-1 et seq.).

14. Will comply with P.L. 93-348 regarding the protection of human subjects involved in research, development, and related activities supported by this award of assistance.

15. Will comply with the Laboratory Animal Welfare Act of 1966 (P.L. 89-544, as amended, 7 U.S.C. §§2131 et seq.) pertaining to the care, handling, and treatment of warm blooded animals held for research, teaching, or other activities supported by this award of assistance.

16. Will comply with the Lead-Based Paint Poisoning Prevention Act (42 U.S.C. §§4801 et seq.) which prohibits the use of lead-based paint in construction or rehabilitation of residence structures.

17. Will cause to be performed the required financial and compliance audits in accordance with the Single Audit Act Amendments of 1996 and OMB Circular No. A-133, "Audits of States, Local Governments, and Non-Profit Organizations."

18. Will comply with all applicable requirements of all other Federal laws, executive orders, regulations, and policies governing this program.

| * SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL | * TITLE |
|---|---|
| Jennifer Teixeira | Director of Sponsored Projects |
| * APPLICANT ORGANIZATION | * DATE SUBMITTED |
| The Regents of the University of California | 02/10/2012 |

**Standard Form 424B (Rev. 7-97) Back**

FORM **CD-511**
(REV 1-05)

CERTIFICATION REGARDING LOBBYING

U.S. DEPARTMENT OF COMMERCE

Applicants should also review the instructions for certification included in the regulations before completing this form. Signature on this form provides for compliance with certification requirements under 15 CFR Part 28, 'New Restrictions on Lobbying.' The certifications shall be treated as a material representation of fact upon which reliance will be placed when the Department of Commerce determines to award the covered transaction, grant, or cooperative agreement.

**LOBBYING**

As required by Section 1352, Title 31 of the U.S. Code, and implemented at 15 CFR Part 28, for persons entering into a grant, cooperative agreement or contract over $100,000 or a loan or loan guarantee over $150,000 as defined at 15 CFR Part 28, Sections 28.105 and 28.110, the applicant certifies that to the best of his or her knowledge and belief, that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, 'Disclosure Form to Report Lobbying.' in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements) and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure occurring on or before October 23, 1996, and of not less than $11,000 and not more than $110,000 for each such failure occurring after October 23, 1996.

**Statement for Loan Guarantees and Loan Insurance**

The undersigned states, to the best of his or her knowledge and belief, that:

In any funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this commitment providing for the United States to insure or guarantee a loan, the undersigned shall complete and submit Standard Form-LLL, 'Disclosure Form to Report Lobbying,' in accordance with its instructions.

Submission of this statement is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who fails to file the required statement shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure occurring on or before October 23, 1996, and of not less than $11,000 and not more than $110,000 for each such failure occurring after October 23, 1996.

**As the duly authorized representative of the applicant, I hereby certify that the applicant will comply with the above applicable certification.**

* NAME OF APPLICANT
The Regents of the University of California

* AWARD NUMBER
N/A

* PROJECT NAME
N/A

Prefix: Mrs.
* First Name: Thea
Middle Name:
* Last Name: Vicari
Suffix:
* Title: Director of Sponsored Projects

* SIGNATURE:
Jennifer Teixeira

* DATE:
02/10/2012

## BUDGET JUSTIFICATION (FIRST YEAR)

**1. Salary & Fringe Benefits: $82,462**

**Principal Investigator support requested: 3 months summer salary**
Professor Carpin will lead the project at UCM and will be responsible for the project and will supervise the two graduate student researchers.

**Graduate Student support requested for all years**
GSR #1 will be responsible for research on grasping.
GSR # 2 will be responsible for improvements to USARSim.

**Fringe Benefits**
Benefits are calculated at actual rate when known.
Faculty Rate: 11%
GSR Rate: 1.4%

**2. Travel: $7,760**
Travel funds include $3,000 for the two GSR to participate in a leading robotics conference (e.g., ICRA, IROS) and present research results obtained in this project. Moreover, upon suggestion of Dr. Steve Balakirsky, $4760 have been budgeted to allow the two GSR to spend two weeks at NIST collaborating with NIST scientists interested in this project. Each student is supposed to spend $700 in roundtrip airfare from Fresno to DC, plus $1680 in lodging, assuming $120/night for 14 days.

**3. Other Direct Costs**

**Graduate Student Tuition/Fee Remission: $59,508**
Graduate Student fees for the 9-month academic year for two non-resident graduate students, advancing to resident candidacy in year two. University policy requires the inclusion of tuition/fee remission for graduate student researchers employed 25% time or more during the academic year. These costs are based on published University rates.

**5. Facilities and Administrative (F & A) Costs: $49,662**
Facilities and Administrative costs were estimated in accordance with UCM's approved indirect cost rate agreement. The on-campus indirect cost rate of 55% of MTDC was used because most project effort, in terms of both FTEs as well as cost, will take place on-campus.

## BUDGET JUSTIFICATION (SECOND AND THIRD YEAR)

**1. Salary & Fringe Benefits: $172,420**

**Principal Investigator support requested: 3 months summer salary in year two and three**
Professor Carpin will lead the project at UCM and will be responsible for the project and will supervise the two graduate student researchers.

**Graduate Student support requested for all years**
GSR #1 will be responsible for research on grasping.
GSR # 2 will be responsible for improvements to USARSim.

**Fringe Benefits**
Benefits are calculated at actual rate when known.
Faculty Rate: 11%
GSR Rate: 1.4%

**2. Travel: $10,760**
For the second year, travel funds include $3,000 for the two GSR to participate in a leading robotics conference (e.g., ICRA, IROS) and present research results obtained in this project. Moreover, upon suggestion of Dr. Steve Balakirsky, $4760 have been budgeted to allow the two GSR to spend two weeks at NIST collaborating with NIST scientists interested in this project. Each student is supposed to spend $700 in roundtrip airfare from Fresno to DC, plus $1680 in lodging, assuming $120/night for 14 days.
For the third year $3000 have been included for the two GSR to participate in a leading robotics conference (e.g., ICRA, IROS) and present research results obtained in this project.

**3. Other Direct Costs**

**Graduate Student Tuition/Fee Remission: $100,917**
Graduate Student fees for the 9-month academic year for two non-resident graduate students, advancing to resident candidacy in year two. University policy requires the inclusion of tuition/fee remission for graduate student researchers employed 25% time or more during the academic year. These costs are based on published University rates ($65,459 for year 2 and $35,456 for year 3)

**5. Facilities and Administrative (F & A) Costs: $100,749**
Facilities and Administrative costs were estimated in accordance with UCM's approved indirect cost rate agreement. The on-campus indirect cost rate of 55% of MTDC was used because most project effort, in terms of both FTEs as well as cost, will take place on-campus.

# COLLEGES AND UNIVERSITIES RATE AGREEMENT

EIN:

ORGANIZATION:
University of California (UCM) Merced Campus
P.O. Box 2039
Merced, CA 95344

DATE:04/28/2011

FILING REF.: The preceding agreement was dated 07/20/2006

The rates approved in this agreement are for use on grants, contracts and other agreements with the Federal Government, subject to the conditions in Section III.

## SECTION I: INDIRECT COST RATES

RATE TYPES: FIXED FINAL PROV. (PROVISIONAL) PRED. (PREDETERMINED)

EFFECTIVE PERIOD

| TYPE | FROM | TO | RATE(%) | LOCATION | APPLICABLE TO |
|---|---|---|---|---|---|
| PRED. | 07/01/2009 | 06/30/2015 | 55.00 | On-Campus | All Programs |
| PRED. | 07/01/2009 | 06/30/2015 | 26.00 | Off-Campus | All Programs |
| PROV. | 07/01/2015 | Until Amended | | (1) | |

*BASE

Modified total direct costs, consisting of all salaries and wages, fringe benefits, materials, supplies, services, travel and subgrants and subcontracts up to the first $25,000 of each subgrant or subcontract (regardless of the period covered by the subgrant or subcontract). Modified total direct costs shall exclude equipment, capital expenditures, charges for patient care, student tuition remission, rental costs of off-site facilities, scholarships, and fellowships as well as the portion of each subgrant and subcontract in excess of $25,000.

(1) Use same rates and conditions as those cited for fiscal year ending June 30, 2015.

NOTE: See Special Remarks regarding Genomic Arrays.

ORGANIZATION: University of California (UCM) Merced Campus

AGREEMENT DATE: 04/28/2011

## SECTION II: SPECIAL REMARKS

TREATMENT OF FRINGE BENEFITS:

This organization charges the actual costs of each fringe benefit per employee direct to Federal projects for all employees whose salary and wages is charged direct to Federal projects. However, for the purpose of budgeting fringe benefit costs under project proposals, the organization uses an average fringe benefit rate which is applied to budgeted salaries and wages. The organization's fringe benefits are:
OASDI, FICA, WORKERS COMPENSATION, HEALTH/DENTAL/OPTICAL/LIFE INSURANCE, ANNUITANT HEALTH AND DENTAL INSURANCE, UNEMPLOYMENT INSURANCE, NON-INDUSTRIAL DISABILITY INSURANCE, INCENTIVE AWARD PROGRAMS, EMPLOYEE SUPPORT PROGRAM, RETIREMENT PLAN, AND TUITION/FEE REMISSION OF CERTAIN STUDENT EMPLOYEES.

TREATMENT OF PAID ABSENCES

Vacation leave costs are charged on the accrual basis of accounting as an assessment to payroll. All other leave costs, including sick, holiday, and other leave costs (e.g., jury duty) are charged on the cash basis of accounting. Leave costs other than vacation are included in salaries and wages and are claimed on grants, contracts and other agreements as part of the normal costs for salaries and wages. Separate claims for the costs of these paid absences are not made. Leave costs are allocated to direct and/or indirect objectives on a prorated basis consistent with the allocation of the employee's salary and wages. Sabbatical leave costs are not charged to sponsored agreements.

DEFINITION OF EQUIPMENT
Equipment is defined as tangible nonexpendable personal property having a useful life of more than one year and an acquisition cost of $5,000 or more per unit.

DEFINITION OF ON-CAMPUS AND OFF-CAMPUS RATES

DEFINITION OF OFF-CAMPUS RATE
The off-campus rate is applicable to those projects conducted at facilities not owned or leased by the University. However, if the project is conducted in leased space and lease costs are directly charged to the project, then the off-campus rate must be used.

PROJECTS CONDUCTED ENTIRELY ON-CAMPUS OR ENTIRELY OFF-CAMPUS:
Projects conducted entirely on-campus or entirely off-campus will be applied the on-campus or off-campus rate respectively.

PROJECTS CONDUCTED PARTIALLY OFF-CAMPUS AND PARTIALLY ON-CAMPUS:
If the project involves work at both on-campus and off-campus sites, either the on-campus or off-campus rate generally should be applied, consistent with where the majority of the work is to be performed. Salary cost is generally accepted as a measure of work performed in terms of the total project.

USE OF BOTH ON-CAMPUS AND OFF-CAMPUS RATES
The use of both on-campus and off-campus rates for a given project may be justified if both of the respective rates can clearly be identified with a significant portion of salaries and wages of the project. For purposes of this provision, significant is defined as approximately 25% or more of the total costs and a project's total salary and wage costs exceed $250,000.

SPECIAL REMARKS: The NIH policy on indirect costs pertaining to Genomic Arrays (NOT-OD-10-097) is effective as of 05/13/10.

ORGANIZATION: University of California (UCM) Merced Campus

AGREEMENT DATE: 04/28/2011

## SECTION III: GENERAL

A. LIMITATIONS:

The rates in this Agreement are subject to any statutory or administrative limitations and apply to a given grant, contract or other agreement only to the extent that funds are available. Acceptance of the rates is subject to the following conditions: (1) Only costs incurred by the organization were included in its facilities and administrative cost pools as finally accepted: such costs are legal obligations of the organization and are allowable under the governing cost principles; (2) The same costs that have been treated as facilities and administrative costs are not claimed as direct costs; (3) Similar types of costs have been accorded consistent accounting treatment; and (4) The information provided by the organization which was used to establish the rates is not later found to be materially incomplete or inaccurate by the Federal Government. In such situations the rate(s) would be subject to renegotiation at the discretion of the Federal Government.

B. ACCOUNTING CHANGES:

This Agreement is based on the accounting system purported by the organization to be in effect during the Agreement period. Changes to the method of accounting for costs which affect the amount of reimbursement resulting from the use of this Agreement require prior approval of the authorized representative of the cognizant agency. Such changes include, but are not limited to, changes in the charging of a particular type of cost from facilities and administrative to direct. Failure to obtain approval may result in cost disallowances.

C. FIXED RATES:

If a fixed rate is in this Agreement, it is based on an estimate of the costs for the period covered by the rate. When the actual costs for this period are determined, an adjustment will be made to a rate of a future year(s) to compensate for the difference between the costs used to establish the fixed rate and actual costs.

D. USE BY OTHER FEDERAL AGENCIES:

The rates in this Agreement were approved in accordance with the authority in Office of Management and Budget Circular A-21 Circular, and should be applied to grants, contracts and other agreements covered by this Circular, subject to any limitations in A above. The organization may provide copies of the Agreement to other Federal Agencies to give them early notification of the Agreement.

E. OTHER:

If any Federal contract, grant or other agreement is reimbursing facilities and administrative costs by a means other than the approved rate(s) in this Agreement, the organization should (1) credit such costs to the affected programs, and (2) apply the approved rate(s) to the appropriate base to identify the proper amount of facilities and administrative costs allocable to these programs.

BY THE INSTITUTION:

University of California (UCM) Merced Campus

(INSTITUTION)

(SIGNATURE)

Peter J. Taylor

(NAME)

Chief Financial Officer

(TITLE)

6/16/11

(DATE)

ON BEHALF OF THE FEDERAL GOVERNMENT:

DEPARTMENT OF HEALTH AND HUMAN SERVICES

(AGENCY)

(SIGNATURE)

Wallace Chan

(NAME)

Director, Western Field Office

(TITLE)

4/28/2011

(DATE) 3097

HHS REPRESENTATIVE: Janet Turner

Telephone: (415) 437-7820

# GRASPING AND SIMULATION FOR NEXT-GENERATION MANUFACTURING ROBOTS

STEFANO CARPIN, PHD
SCHOOL OF ENGINEERING
UNIVERSITY OF CALIFORNIA, MERCED
HTTP://ROBOTICS.UCMERCED.EDU

| | |
|---|---|
| **Funding opportunity title:** | Measurement Science and Engineering (MSE) Research Grant Programs for the Engineering Laboratory (EL) |
| **Funding opportunity number:** | 2012-NIST-MSE-01 |
| **CFDA Number(s):** | 11.609, Measurement and Engineering Research and Standards |
| **Areas** | Manufacturing, Dexterous Manipulation, Intelligent Planning, High-fidelity Simulation |
| **Duration** | one year, plus options for two more years |
| **Period of performance:** | August 15, 2012 – August 14, 2013 (first year)<br>August 15, 2013 – August 14, 2015 (optional second and third year) |
| **Requested budget:** | $199,352 (first year)<br>$209,137 (second year)<br>$175,708 (third year) |

# Part 1. Year One

## 1. Context and Objectives

Revitalizing manufacturing in the US is crucial for long term economic prosperity and national security [39], and robotics is crucial to sustain a healthy manufacturing sector. Formerly developed industrial manipulators were expected to perform the same operation for extended periods of time while operating in perfectly conditioned work cells. But next generation manufacturing robots are envisioned to operate side by side with humans in unstructured environments while performing a variety of tasks. The roadmap for US robotics presented in 2009 to the US Congressional Robotics Caucus identified various manufacturing scenarios to be pursed within five, ten, and fifteen years [29]. All of them hinged on the idea of *flexible manufacturing robots* that can be easily redeployed and reprogrammed to quickly respond to rapidly changing demands. These robots are best described as intelligent assistive design (IAD). The document further states that "Substantial progress in manipulation is needed for almost all of the service robotics applications." Indeed, a robotic co-worker must be capable of using the same tools used by a human, must be able to operate in a ever changing environment, and, above all, must be certifiably safe for humans.

Grasping and manipulation is one of the most challenging areas of robotics because it requires significant progress both in hardware and on the algorithmic side. Besides the necessity of developing new robotic hands superseding the parallel-jaw paradigm, the whole field is being completely redefined by the requisite of designing algorithms capable of handling non-rigid objects (e.g. flexible or soft) and objects for which the robot has not been explicitly programmed. While towel-folding may have become the most known example [33] involving flexible objects, the spectrum of possible applications is much wider. Using one or two hands, an ideal robotic companion should be able to manipulate a variety of rigid and flexible objects for which an explicit physical model is not available. Moreover, the robot shall complete its manipulation task while obeying to protocols ensuring certifiable safety for human workers operating side-by-side with the robot.

Based on the above scenario, we offer two deliverables. First, we propose to produce a primer on robotic grasping with a particular emphasis on grasping paradigms needed to implement the aforementioned vision. This document will encompass the entire field of grasping research using advanced robotic hands including perception, grasp models, grasping algorithms, hand pose determination based on hand kinematics and performance measurements used for assessing grasp results. The second item is the development of programmable avatars to be included in USARSim. USARSim

emerged as a leading environment for robotic simulation, but lacks an agile way to incorporate human characters in simulation. Including easy to program avatars will offer the possibility to test safety protocols for robotic manipulators under repeatable and controllable conditions. The two deliverables will be integrated together in a end-of-year mixed-reality demo, where a robotic companion will collaborate with a human in a task involving grasping and manipulation. The demo will be run in simulation first and then, once tuned, the code will be moved *as is* on a real robot and the same operations will be done while collaborating with a human.

The work will be carried out at the University of California, Merced, with the contribution of two graduate students enrolled in the graduate program in Electrical Engineering and Computer Science. UC Merced is the newest research university in the US and is a minority serving institution.

## 2. A Primer on Robotic Grasping

Grasping has a rich and multifaceted history in robotics [36] and it dates back to the development of the first robotic hands. The introduction of dexterous, multifingered robotic hands led to the development of sophisticated mathematical tools to solve questions related to grasp synthesis and analysis. A large body of literature is based on the assumption that some sort of geometrical model of the object to be grasped or manipulated is available. When this is the case, the problem can be addressed using elegant formalisms, like for example [34]. However, most of this early work is based on assumptions rarely met when considering the flexible manufacturing scenario depicted above. In particular, these methods are based on analytic expressions relying on the availability of friction coefficients and other physical quantities that will be too time consuming to collect when robots will be used in rapidly changing scenarios.

The advent of new sensors (e.g., Microsoft Kinect), rapid developments in machine learning, and dramatic improvements in computational speed recently led to results largely unthinkable only a few years ago. Saxena et al. [38] demonstrated for the first time a robot capable of grasping rigid objects it never saw before and for which no model was given. Their method is based on supervised machine learning and assumes the robot is equipped with a stereocamera to inspect the scene while operating. Interestingly, this successful system entirely disregards most of the formerly developed literature in the area of grasping. More recently, Abbeel and coworkers demonstrated the first robot capable of manipulating towels [33]. Their work is also based on machine learning, though it makes a number of assumptions concerning the cloth being folded. Balaguer and Carpin have also very recently demonstrated

that folding can be achieved while removing most of the hypotheses introduced by Abbeel, and just learned from a small number of examples given by a human via reinforcement learning [6]. One of the most regarded surveys on grasping is more than ten years old [19] and ignores all these methods because they rely on algorithms and sensors only recently introduced.

**Goal:** Develop an up-to-date robotic primer on grasping including contemporary developments based on machine learning and the latest generation sensors.

## 3. Integration of Avatars in USARSim

USARSim currently lacks the possibility to easily integrate virtual characters into simulated environments. This feature is utterly needed in order to assess how intelligent manufacturing systems respond to human interactions and interferences. Interaction with humans is central to establishing and certifying robot safety when operating in unstructured environments with humans. This evaluation is important for automated ground vehicles (AGV), autonomous pallettizers, static manipulators, and mobile manipulators. The technology to implement this extension to USARSim is available, although scattered. However, even though it is available, it is not easy to use for the casual user. The Unreal Engine offers since its very inception a set of tools to attach intelligent scripts to control pawn characters within the game. These scripts (known as *AIScripts*) can be activated through a rich set of programmable triggers. More recently, UDK uses Kismet, a visual interface to create scripts more easily. However, these tools are still designed for game level designers. On the other hand, researchers in computer graphics and virtual environments have investigated since quite some time the possibility to easily program interactive virtual characters, also called conversational characters [31, 35, 40]. These characters are commonly used for training purposes, education and the like, and offer the possibility to specify gestures, speech, and motions with a varying degree of accuracy. These languages, often based on markup approaches, are meant to be used by non-specialists interested in designing compelling learning or entertainment experiences.

The goal of this second package is to develop an easy to use interface to program virtual interactive characters with behaviors that can be useful for performance measurement of intelligent manufacturing robots engaged in a variety of tasks to be performed in close proximity to humans. This goal will be pursued by exploring two alternatives. The first one consists of developing wrappers to interface existing virtual characters languages with USARSim. Should this approach turn out to be feasible, it would open the doors to reuse a significant amount of preexisting animation code. Alternatively, the possibility to adapt a simple behavioral language

will be considered[1]. In this second scenario, one would possibly simplify some of the existing languages in order to support only those constructs really needed in the situations of interest. The final choice will rely not only on technical considerations related to the available man power, but also on iterations with NIST personnel in order to jointly identify the paradigm more appropriate for the end users.

**Goal:** Extend the simulation infrastructure with the possibility to easily program virtual characters moving in simulated virtual environments.

## 4. Integrated Demo

As proof of concept, in summer 2013 we will develop a demo with humans cooperating with manufacturing robots. The demo will take advantage of the state of the art robotic facilities available at UC Merced, and will build upon the two work packages formerly described (see figure 1).

One such scenario could involve, for example, a human passing a series of objects to the robot for its storage in a box. Objects passed to the robots would be novel and the robot shall grasp and move them using one or both hands without harming the human. The algorithms will be first tested and tuned in USARSim only. In the next stage the human would perform its actions, the robot would process its sensor data and formulate motion plans, but its execution would happen in USARSim only. In order to increase realism in USARSim, human motions will be tracked by the motion capture and mapped to the human avatar in USRASim, thus offering a faithful reproduction of actions happening in the real world. Finally, after the whole system has been tested and tuned, the whole task would be completed with the human interacting with the robot.

**Goal:** Implement demo integrating humans cooperating with robot manipulators in reality and in USARSim.

[1] *Behavioral language* is a term commonly used in computer animation to describe tools to program virtual characters. The term however is unrelated to behavior-based approaches proposed in robotics.

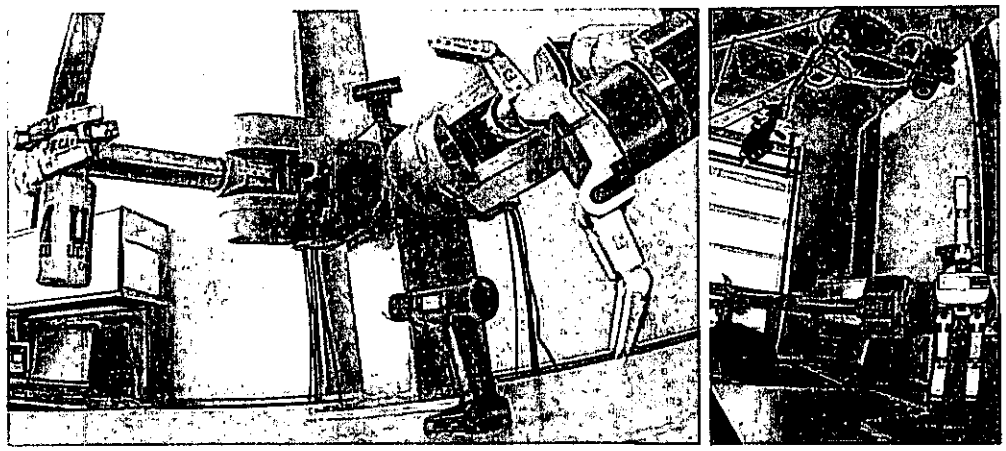

FIGURE 1. On the left, a dual manipulator currently being used in the UC Merced robotics lab. The robot includes two 7-dof Barrett WAM arms, each equipped with the multifingered Barrett Hand. Its robotic head consists of a Bumblebee 2 stereo camera mounted on two servos offering two degrees of freedom (yaw and pitch). The right figure shows the Vicon motion capture infrastructure surrounding the robot. The system can track markers with submillimiter accuracy at a frequency of 120Hz. All the equipment is readily available for this project and has been acquired with the support of the National Science Foundation.

## 5. PERSONNEL WORKING ON THE PROJECT AND INSTITUTIONAL CAPABILITIES OF THE PROPOSING INSTITUTION

Thanks to a multi-year collaboration with NIST dating back to 2005 and witnessed by numerous joint publications [1, 2, 11, 12, 13, 14, 15, 16, 17, 18, 24, 25, 28, 32, 37], the proposing group is uniquely qualified for the this project.

Stefano Carpin (PI) is Associate professor of engineering at the University of California, Merced since 2007. He obtained a PhD in Electrical Engineering and Computer Science from the University of Padova (Italy) in 2003, and before joining UC Merced he held faculty positions at Jacobs University Bremen (Germany) between 2003 and 2006. Dr. Carpin has more than ten years of experience in robotics research, and published more than 90 in leading international journals and conferences. He regularly serves in the program committee of the major international robotics conferences organized by the IEEE (ICRA, IROS) and since May 2010 is an Associate Editor of the IEEE Transactions on Robotics. Dr. Carpin has been one of the early developers of USARSim and his research group has continuously contributed to its

improvement. Dr. Carpin's research includes autonomous navigation and motion planning [26, 27], cooperative robotics [23, 30], service robotics [20, 21, 22], and robotic manipulation [3, 4, 5, 6, 7, 8, 9, 10].

In 2007 Dr. Carpin established the robotics laboratory at the University of California, Merced, the newest campus in the University of California system. The lab is currently equipped with state of the art robotic systems. These include two ActiveMedia P3AT mobile platforms, various aerial robots, two humanoid robots (Hoap 3 and Bioloid) and the the humanoid robotic torso previously described (see figure 1). The robotics lab is located in the school of engineering and features 9 working stations fully equipped with state of the art personal computers and a small shop for robot customization and repairs. A full scale machine shop is managed by the school of engineering and available for a nominal fee. Standard computing infrastructure (servers, software, etc.) is provided by the school of engineering or has already been acquired by the PI with previous grants. The School of Engineering offers an undergraduate degree in Computer Science Engineering and a graduate program in Electrical Engineering and Computer Science. Robotics education and research are integrated into these programs, and skillful students are available to contribute to this project.

## Part 2. Years two and three (optional)

### 6. Grasping

In the second and third year we will move into actual development and implementation of algorithms for robotic grasping. Building upon our recent work, our goal will be to develop machine learning-based grasping and manipulation algorithms enabling robots to perform tasks while working in unstructured environments and offering certified safety when operating side-by-side with humans. We maintain machine learning offers the right framework to implement levels of competence not bound to specific conditioning of the robot workspace and able to correctly operate also when interacting with novel objects. Moreover, differently from many classic approaches, these algorithms are easier to adapt to take advantage of rapidly evolving sensor devices offering more and more sophisticated and informative data. Our contributions will be first tested and tuned in USARSim, and then implemented on the formerly described robotic system available at UC Merced. Algorithms will be designed to guarantee independence from the underlying robotic hardware, and we will provide implementation guidance to reproduce the same results on the robotic systems available at NIST.

As part of this effort, we will also work on benchmarks for robotic grasping. Robot benchmarking has gained significant traction in recent years, also because of the PerMIS workshop organized by NIST, but a coherent body of benchmarks is still missing. However, manufacturing and grasping are two areas where significant progress can be expected. Whereas other tasks commonly found in mobile robotics are harder to characterize in a non ambiguous way, grasping tasks lend themselves to a more principled approach. In grasping, manipulation, and manufacturing it is easier to envision a set of levels of competence transcending the specific robotic system used to implement them. This is not the case for many tasks in mobile robotics, e.g., mapping or navigation. Our goals will be: survey existing literature produced by scientists and practitioners; identify operationally relevant tasks amenable to constitute a benchmark; rigorously define a set of benchmarks requiring increasingly more complex skills; implement and demonstrate on real robotic hardware different algorithms addressing these benchmarks.

## 7. USARSim Improvements

USARSim currently lacks the ability of faithfully simulating grasping actions. Integrating this feature is critical to tune complex planning systems for manufacturing. With the goal of being able to implement and study grasping algorithms of different complexity within USARSim, we propose to develop an external application exclusively dedicated to handling this aspect of simulation. We dub this application the Manipulation Server (MS). Such an approach has already been explored in USARSim in the past. For example, a Wireless Simulation Server (WSS) has been developed to model signal degradation in wireless communication, and visual feedback, is also handled by an external application. Communication between USARSim and these applications is implemented via TCP/IP. By constraining the amount of exchanged information there is minimal introduced overhead. This is especially the case when both applications are executed on the same machine. From a practical point of view, one has to recognize that even in applications where robotic manipulation is pivotal, not all objects in the simulated (or real) environments will be manipulated by the robot itself. At the same time, determining whether a grasp takes place or not requires the availability of detailed geometrical models and physical properties, e.g. friction. Our proposed design exploits the object-oriented nature of UnrealScript to model these aspects. Specifically, a new class of *graspable objects* will be introduced to model only the objects that can be grasped. Detailed geometrical models and physical properties will therefore be needed only for instances of this class. In the main simulation cycle, MS will be invoked only when the grippers are sufficiently close to one of these graspable objects, thus limiting the overhead. Fig. 2 sketches the involved blocks and provides additional details about this idea. The advantages

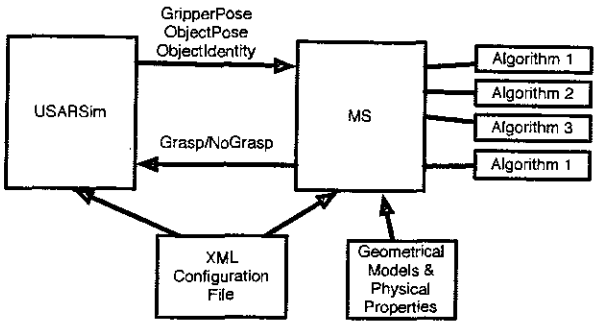


FIGURE 2. A configuration file indicates which objects in the environment are graspable, and where their geometrical models are located. At startup MS reads the configuration file and loads the models. During the simulation cycle USARSim queries MS when a gripper and a graspable object are sufficiently close, and MS determines whether a grasp occurs. MS answers these queries based on the geometrical models, the pose of the gripper and the object, and using one of the available algorithms. Some algorithms known in literature (blue) will be implemented during this project, but the system will also capable of dynamically loading algorithms developed by the end users (red).

of the proposed architectural solution are the following: 1) all existing simulation environments can be reused with no change; 2) the manipulation server will be run only for tasks where manipulation is relevant. Users who do not use this feature will see no performance degradation because of this added component; 3) different manipulation algorithms will be available for selection at startup, thus offering a level of detail commensurate with the purposes of the simulation being performed; 4) by standardizing the interface between USARSim and MS and using dynamically linked plugins, end-users will have the possibility to experiment and integrate their own grasp prediction algorithms into more sophisticated simulation environments. Moreover, end-users will code their extensions in a mainstream language like C/C++ rather than the specialized UnrealScript host language.

## 8. INTEGRATED DEMOS

Similarly to the integrated demo for the first year, various demonstrations combining the two efforts will be implemented upon consultation with NIST personnel.

## 9. DECLARATIONS

A request for funding this project has not been submitted to any other funding agency.

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