USC Iovine and Young Academy

Arts, Technology and the Business of Innovation

IDSN-536: Designing Networked Objects: From IoT to Smart Environments [DRAFT]

Units: 4.0

Spring 2025 - T/R, 5:00pm - 6:50pm

Location: IYH 110 and Online

Instructor: Aaron Siegel
Office: IYH 212 or Zoom meeting room listed on Brightspace.
Office Hours: In person: Wednesdays, 12:00pm - 2:00pm.
Zoom: Wednesdays, 5pm - 7pm.
Contact Info: aaronsie@usc.edu

IT Help:
https://uscedu.sharepoint.com/sites/IYAStudent/SitePages/IT-Resources.aspx
Hours of Service: M-F, 8:30am - 6:30pm
Contact Info: iyahelp@usc.edu, 213-821-6917

Course Description

Designing Networked Objects: From IoT to Smart Environments is a course that intends to introduce students to concepts of interaction design through the medium of physical computing. Students will become familiar with the technological basics of internet telephony, electrical engineering, and computer programming in order to create innovative interactive experiences in physical objects.

Learning Objectives and Outcomes

- Fundamentals of physical computing through the use of microcontrollers.
- Concepts related to the aesthetic considerations of interactivity and smart product design.
- Networked communication of internet connected objects.
- Telepresent experiences through computer-mediated systems, interfaces, and objects.

Prerequisite(s): None.
Co-Requisite(s): None.
Concurrent Enrollment: None.

Recommended Preparation

IDSN 530: Technology Essentials. Basic knowledge of the principles of internet connectivity. JavaScript/Arduino.

Course Notes

This course will be conducted online in an entirely synchronous fashion. Students will be required to complete the readings and any assigned projects before the synchronous class session occurs.

Technological Proficiency and Hardware/Software Required

Students must provide their own laptop. The laptop specifications take into consideration that students will be creating, streaming and downloading audio and video, communicating using video conferencing applications and creating and storing large multimedia files. You will need appropriate USB adaptors if you have only USB-C ports on your computer.

Required Readings and Supplementary Materials

- ELEGOO UNO Project Super Starter Kit with Tutorial and UNO R3 Compatible with Arduino IDE.
- Arduino Uno Wifi Rev2.
- Banzi, Massimo. *Make: Getting Started with Arduino*. 2015.
- Clark, Andy. *Natural-Born Cyborgs*. 2003.
- Manovich, Lev. *Introduction to Info-Aesthetics*. 2008.
- Objectified. 2009 [1h 15m].

Grading Breakdown

Manovich Essay Response Paper	5%	Hardware Interface Assignment	5%
Getting Started with Arduino Response Paper	5%	Interaction Proposal	10%
Natural Born Cyborgs Response Paper	5%	Refined Interaction Proposal	5%
Objectified Response Paper	5%	System Assignment	5%
Group Accountability Paper	5%	Product Visual Identity	5%
Lab Exercises (1% each, 25 total)	25%	Final Assignment	20%

Grading Scale

	B+ = 89 - 87	C+ = 79 - 77	D+ = 69 - 67	
A = 100 - 95	B = 86 - 83	C = 76 - 73	D = 66 - 63	F = 59 and below
A- = 94 - 90	B- = 82 - 80	C- = 72 - 70	D- = 62 - 60	

Assignment Submission Policy

All assignments must be delivered, as per instructor guidance, on the date and time. No exceptions. (Early submissions are, of course, encouraged!) Read and heed supplementary Assignment Details, distributed when each assignment is launched, carefully.

Late Submissions

Assignments will be accepted after the deadline with the following grade penalties. Do not ask for extensions; the below *are* the extensions.

- Submission in the 24 hours after the deadline — 10% deduction
- Submission between 24 and 48 hours after the deadline — 20% deduction
- Submission between 48 hours and 3 days after the deadline — 50% deduction
- Submission more than 3 days after the deadline — 100% deduction

Keep copies of all your files and emails until the end of the semester.

Correcting a Grading Error or Disputing a Grade

If you don't inform the instructor of missing or incorrect grades within two weeks of those grades being posted, the grades will be assumed correct. Do not wait until the semester's end to check or appeal any grades. If you feel a grade merits re-evaluation, you are encouraged, within one week of the instructor providing a grade and initial feedback, to send the instructor a memo in which you request reconsideration. The memo should include a thoughtful and professional explanation of your concerns. Be aware that the reevaluation process can result in three types of grade adjustments: positive, none, or negative. (Note: Complaints on the date of a graded assignment returned to you will not be addressed; it is essential to wait one full day prior to raising a concern.)

Course Attendance Policy

The Academy maintains rigorous academic standards for its students and on-time attendance at all class meetings is expected. Each student will be allowed ***two absences*** over the course of the semester for which no explanation is required. Students are advised not to waste absences on non-critical issues, and to use them carefully for illness or other issues that may arise unexpectedly. Except in the case of prolonged illness or other serious issue (see below), no additional absences will be excused. Each additional absence will result in the lowering of the final grade by ⅓ of a grade (e.g., an A will be lowered to A-, and A- will be lowered to a B+, etc.). In addition, three tardies will equal a full course absence. Students remain responsible for any missed work from excused or unexcused absences. Immediately following an absence, students should contact the instructor to obtain missed projects or lecture notes and to confirm new deadlines or due dates. Extensions or other accommodations are at the discretion of the instructor.

Automatically excused absences normally may not be used for quiz, exam, or presentation days. Using an excused absence for a quiz, exam, or presentation, such as in the case of sudden illness or other emergency, is at the discretion of the instructor. In the case of prolonged illness, family emergencies, or other unforeseen serious issues, the student should contact the instructor to arrange for accommodation. Accommodation may also be made for essential professional or career-related events or opportunities. All accommodations remain at the discretion of the instructor, and appropriate documentation may be required.

Course Content Distribution and Synchronous Session Recordings Policies

USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. (Living our Unifying Values: The USC Student Handbook, page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been distributed to students or in any way had been displayed for use in relationship to the class, whether obtained in class, via email, on the internet, or via any other media. (Living our Unifying Values: The USC Student Handbook, page 13).

Participation

Students are expected to actively participate in this course. In an online forum, participation includes:

- Careful reading and viewing of assigned materials by the date due
- Regular, substantive contributions to discussions
- Active engagement with online content
- On-time attendance and full attention in synchronous sessions
- Significant collaboration with classmates and teammates

Course grades may be affected for students who do not contribute to the course through active participation. Students should notify the instructor in advance if they are unable to attend class. Those unable to attend will be required to review the online recording for the session missed, and submit thoughtful feedback to the Instructor.

Classroom Norms

Students are requested to stay off of their phones during the class session. All discussion in class should be focused on the course material currently being covered. Students should be considerate and respectful of their classmates and ensure that any criticism of work is constructive and delivered in a positive manner.

Zoom Etiquette

Students are expected to participate with their camera on. If a student is unable to keep their camera on during the synchronous Zoom session, they should contact the instructor prior to the class session. You should participate from a location that affords you to concentrate on the class material as well as prevent any audio-visual disruptions when participating in discussions and collaborative exercises with classmates.

Course Schedule:

DAY	TOPICS	READINGS	DELIVERABLES
Week 1 - Introduction			
1/14	**Lecture: Interaction Design for Computers** ● Cybernetics ● Hypermedia ● Human-Computer Interface ● Software Interface ● Hardware Interface ● Context, Location		
1/16	**Workshop: Physical Computing Fundamentals** ● Schematics ● Wiring Diagrams ● Arduino Code **In-Class Work** ● Labs		Lab #0: Installing IDE Lab #1: Add Libraries and Open Serial Monitor
Week 2 - Interaction Design			
1/21	**Lecture: The Electronic Brain** ● Sensing & Actuating ● Haptics	READ: Manovich - Introduction to Info-Aesthetics (2008).	DUE: Manovich Essay Response Paper.
1/23	**Workshop: Electrical Engineering Fundamentals** ● Ohm's Law ● Components ● Load and Logic **In-Class Work** ● Labs		Lab #2: Blink Lab #3: LED
Week 3 - Communication Fundamentals			
1/28	**Lecture: Communications Technologies** ● Networks / Servers / Clients ● Writing ● Remote Communication ● Electronic and Digital Communication ● Telepresence	READ: Banzi, ch. 1-4.	

1/30	**Workshop: FTP** ● FileZilla ● Account Credentials ● Directory Structure **In-Class Work** ● Labs		Lab #4: RGB LED Lab #5: Digital Inputs
Week 4 -			
2/4	***Hardware Interface Presentations***	READ: Banzi, ch. 5, 7.	DUE: Hardware Interface Assignment.
2/6	**Workshop: Github** ● Getting Started ● Student Account ● Repositories ● Commits/Push/Pull **In-Class Work** ● Labs		Lab #6: Active Buzzer Lab #7: Passive Buzzer
Week 5 -			
2/11	**Lecture: Human Evolution** ● Tool + Technique = Technology ● Augmenting the Body ● Cyborgs	READ: Clark, ch. 1-2.	
2/13	**Workshop: Heroku** ● Getting Started ● Making a Project ● Deploying a Dyno **In-Class Group Work** ● Labs		Lab #8: Tilt Ball Switch Lab #9: Servo
Week 6 -			
2/18	**In-Class Group Work** ● Interaction Proposal Development	READ: Banzi, ch. 8. READ: Clark, ch. 3-4.	DUE: *Getting Started with Arduino* Response Paper.
2/20	**Workshop: Microcontroller Networking** ● Connecting ● Transmitting ● Receiving ● Pairs ● Events **In-Class Group Work** ● Labs		Lab #10: Ultrasonic Sensor Lab #11: Temperature and Humidity Sensor

Week 7 -			
2/25	**Lecture: Computer-Mediated Human Contact** ● Science Fiction Interfaces ● Virtual Reality ● Teledildonics ● Relationship Ethics	READ: Clark, ch. 5-6.	
2/27	**Workshop: Advanced Electronics** ● Sensor Kits ● Motors ● High Voltage Relays **In-Class Group Work** ● Labs		Lab #12: Analog Joystick Lab #13: Infrared Receiver
Week 8 -			
3/4	***Interaction Proposal Presentations***		DUE: Interaction Proposal.
3/6	**In-Class Work: Interaction Proposal Refinement** ● Group Breakouts ● Refine ideas based on feedback		
Week 9 -			
3/11	**In-Class Work: Interaction Proposal Refinement** ● Group Breakouts ● Refine ideas based on feedback	READ: Clark, ch. 7-8.	DUE: *Natural Born Cyborgs* Response Paper.
3/13	**Workshop: Service Development** ● Database Configuration ● Application Programming Interface ● User Management **In-Class Group Work** ● Labs		DUE: Refined Interaction Proposal Lab #14: LCD Display Lab #15: Thermometer
Spring Break			
3/18	*No class.*		
3/20	*No class.*		
Week 10 -			
3/25	**Lecture: Smart Products** ● Artificial Intelligence ● Data Management and Display ● Service and Connectivity ● Value Offering	WATCH: Objectified (2009) [1h15m]. READ: Rams - 10 Principles of Good Design	DUE: *Objectified* Response Paper.
3/27	**In-Class Group Work** ● Labs		Lab #16: Eight LED Module Lab #17: Serial Monitor

Week 11 -			
4/1	TBD		
4/3	**In-Class Group Work** ● Labs		Lab #18: Photocell Lab #19: 74HC595 and Segment Display
Week 12 -			
4/8	**Lecture: Infrastructure and Sustainability** ● Servers, Software, Libraries ● Materials, Mechanics, Actuators ● Longevity, Performance ● Maintenance, Upgrades ● Open Source Community ● PCB and SMD Manufacturing ● Environmental Impact		DUE: System Assignment.
4/10	**In-Class Group Work** ● Labs		Lab #20: Four Digital Seven Segment Display Lab #21: DC Motors
Week 13 -			
4/15	**Lecture: Evaluation & Iteration** ● User Testing ● Service Debugging ● Contingency Management ● Additional Features ● Optimization and Refinement ● Production and Manufacturing		DUE: Product Visual Identity.
4/17	**In-Class Group Work** ● Labs		Lab #22: Relay Lab #23: Stepper Motor
Week 14 -			
4/22	**Lecture: Hazards of Networked Objects** ● Forced Obsolescence ● Objects as Services ● Privacy in a Networked World		
4/24	**In-Class Group Work** ● Lab		Lab #24: Controlling Stepper Motor w/ Remote
Week 15 -			
4/29	**In-Class Group Work** ● Finalizing API connectivity.		

5/1	**In-Class Group Work** ● Documentation Preparation. ● Photos / Video / Technical Documents. ● Presentation Slide Preparation.		
FINALS			
5/8	***Final Presentations***		DUE: Final Assignment. DUE: Group Accountability Paper.

Assignments

1. *Manovich Essay Response Paper* **(5%)** (Due: 1/21):
   Write a one page paper in response to reading the Manovich essay *Introduction to Info-Aesthetics.* You should submit your paper as a link to a Google Doc file so that I can add comments and review the revision history to evaluate how you have edited and iterated on your ideas. Make sure there are proper sharing permissions across USC accounts. Review the policy for use of generative AI tools.

2. *Hardware Interface Assignment* **(5%)** (Due: 2/4):
   Come up with a new type of hardware interface based around a singular purpose. Design as if you are working on a science fiction film and you can create any type of tangible interface available. The primary limitation is that the interface elements must be physical (not virtual elements on a screen). Your interface must accommodate at least three (3) different functions. Some virtual elements can be used to augment the interface and indicate status, mode, progress, etc.

   Present your hardware interface as a 16x9 slide deck with as many visuals and as much descriptive text as possible to help communicate the functionality of your device. Submit your final presentation document as a PDF file via Blackboard.

3. *"Getting Started with Arduino" Response Paper* **(5%)** (Due: 2/18):
   Write a one page paper in response to reading the book *Getting Started with Arduino.* You should submit your paper as a link to a Google Doc file so that I can add comments and review the revision history to evaluate how you have edited and iterated on your ideas. Make sure there are proper sharing permissions across USC accounts. Review the policy for use of generative AI tools.

4. *Interaction Proposal* **(10%) (Group)** (Due: 3/4):
   Create a presentation that proposes a new type of interaction between multiple people over the internet. The interaction should tap into some sense of empathy or engagement that encourages or rewards people to continue interacting. Consider aspects like gamification, notifications, and the network effect that will help be a catalyst for more people to take part in the interaction. This proposal should be preparation for the devices you intend to make for the final assignment.

   Present your interaction proposal as a 16x9 slide deck with as many visuals and as much descriptive text as possible to help communicate the functionality and experience of your interaction. Submit your final presentation document as a PDF file via Blackboard. Only one member of your team needs to submit.

5. *"Natural Born Cyborgs" Response Paper* **(5%)** (Due: 3/11):
   Write a one page paper in response to reading the book *Natural Born Cyborgs.* What are your current thoughts on how technology enables humans to become more of a hybrid being? You should submit your paper as a link to a Google Doc file so that I can add comments and review the revision history to

evaluate how you have edited and iterated on your ideas. Make sure there are proper sharing permissions across USC accounts. Review the policy for use of generative AI tools.

6. *Refined Interaction Proposal* **(5%) (Group)** (Due: 3/13):
   After receiving feedback from your initial presentation, refine your idea to be more engaging, captivating, pragmatic, detailed, or whatever quality was falling short in your original proposal. If this is a pivot or an entirely new proposal, make it clear. If your idea was clear and had little to no notes initially, then take this as an opportunity to develop a game plan and trajectory for design and development of your project.

7. *"Objectified" Response Paper* **(5%)** (Due: 3/25):
   Write a one page paper in response to watching the documentary *Objectified*. What insights did you garner that you might apply toward your own product or interaction design project? You should submit your paper as a link to a Google Doc file so that I can add comments and review the revision history to evaluate how you have edited and iterated on your ideas. Make sure there are proper sharing permissions across USC accounts. Review the policy for use of generative AI tools.

8. *System Assignment* **(5%) (Group)** (Due: 4/8):
   Propose a design for a system that will facilitate a specific type of interaction over telecommunication and computer mediated means. The system should be able to facilitate the transmission and storage of data, events caused by sensed input, and retrieval of latest events for actuation. Including information about what input is received by your devices, the required hardware components for sensing, the database schema required for storage of sensed data, and the type of hardware components required for expressing physical output of interaction activity. This planning document should be preparation for the infrastructure needed to support the functionality of your devices being created for the final assignment.

   Present your system description as a 16x9 slide deck with as many visuals and as much descriptive text as possible to help communicate the functionality and technical requirements of your system. Submit your system assignment document as a PDF file via Blackboard. Only one member of your team needs to submit.

9. *Product Visual Identity* **(5%) (Group)** (Due: 4/15):
   Create a visual identity that will establish a brand image surrounding your final product. This should include considerations for a logo design, typography, color, clearspace, as well as any additional design styles (shadows, textures, patterns, iconography, etc).

   Present your visual identity as a style guide in a 16x9 slide deck. Submit your visual identity document as a PDF file via Blackboard. Only one member of your team needs to submit.

10. *Final Assignment* **(20%) (Group)** (Due: 5/8):
    Networked object connected with one or more of your classmates. The sensory input of one object should communicate and translate to the sensory output of another object. The objects should use Wifi enabled Arduino microcontrollers to handle the logic and communications. The objects must be physical in some manner and use some type of sensing/actuating in order to communicate behaviors with the user. Document the functionality of your networked objects through well shot and edited video as well as still photos.

    Present your final assignment as a 16x9 slide deck with as many visuals and as much descriptive text as possible to help communicate the development process, functionality of your objects, and what future potential the devices could have as commercial quality products. Submit your final presentation document as a PDF file in a ZIP file with the rest of your documentation via Blackboard. Only one member of your team needs to submit.

11. *Group Accountability Paper* **(5%)** (Due: 5/8):
    It's important to reflect on how your group has worked together to meet the checkpoints and execute your networked objects projects. Write a paper with a paragraph about each of your group mates and how they contributed to the project. You will then write a paragraph about your contributions. The whole thing needs to be no longer than a page. They are private and will not be shared with your group mates, so it's important to be honest about any occurrences of communication difficulty or failing to contribute in one way or another.

Statement on Academic Conduct and Support Systems

Academic Integrity

The University of Southern California is foremost a learning community committed to fostering successful scholars and researchers dedicated to the pursuit of knowledge and the transmission of ideas. Academic misconduct is in contrast to the university's mission to educate students through a broad array of first-rank academic, professional, and extracurricular programs and includes any act of dishonesty in the submission of academic work (either in draft or final form).

This course will follow the expectations for academic integrity as stated in the USC Student Handbook. All students are expected to submit assignments that are original work and prepared specifically for the course/section in this academic term. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s). Students suspected of engaging in academic misconduct will be reported to the Office of Academic Integrity.

Other violations of academic misconduct include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

Academic dishonesty has a far-reaching impact and is considered a serious offense against the university. Violations will result in a grade penalty, such as a failing grade on the assignment or in the course, and disciplinary action from the university itself, such as suspension or even expulsion.

For more information about academic integrity see the student handbook or the Office of Academic Integrity's website, and university policies on Research and Scholarship Misconduct.

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment or what information requires citation and/or attribution.

Policy for the use of AI Generators

Learning to use AI is an emerging skill, and I welcome the opportunity to meet with you to provide guidance with these tools during office hours or after class. Keep in mind the following:

- AI tools are permitted to help you brainstorm topics or revise work you have already written.
- If you provide minimum-effort prompts, you will get low-quality results. You will need to refine your prompts to get good outcomes. This will take work.
- Proceed with caution when using AI tools and do not assume the information provided is accurate or trustworthy. If it gives you a number or fact, assume it is incorrect unless you either know the correct answer or can verify its accuracy with another source. You will be responsible for any errors or omissions provided by the tool. It works best for topics you understand.
- AI is a tool, but one that you need to acknowledge using. Please include a paragraph at the end of any assignment that uses AI explaining how (and why) you used AI and indicate/specify the prompts you used to obtain the results. Failure to do so is a violation of academic integrity policies.

- Be thoughtful about when AI is useful. Consider its appropriateness for each assignment or circumstance. The use of AI tools requires attribution. You are expected to clearly attribute any material generated by the tool used.

Statement on University Academic and Support Systems

Students and Disability Accommodations:
USC welcomes students with disabilities into all of the University's educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Student Financial Aid and Satisfactory Academic Progress:
To be eligible for certain kinds of financial aid, students are required to maintain Satisfactory Academic Progress (SAP) toward their degree objectives. Visit the Financial Aid Office webpage for undergraduate- and graduate-level SAP eligibility requirements and the appeals process.

Support Systems:
Counseling and Mental Health - (213) 740-9355 – 24/7 on call
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

988 Suicide and Crisis Lifeline - 988 for both calls and text messages – 24/7 on call
The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline consists of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL) – 24/7 on call
Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

Office for Equity, Equal Opportunity, and Title IX (EEO-TIX) - (213) 740-5086
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment - (213) 740-2500
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

The Office of Student Accessibility Services (OSAS) - (213) 740-0776
OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

USC Campus Support and Intervention - (213) 740-0411
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity, Equity and Inclusion - (213) 740-2101
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-1200 – 24/7 on call
Non-emergency assistance or information.

Office of the Ombuds - (213) 821-9556 (UPC) / (323-442-0382 (HSC)
A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

Occupational Therapy Faculty Practice - (323) 442-2850 or otfp@med.usc.edu
Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.