Sensors and actuators lecture notes

Arduino senses the environment by receiving inputs from add-on devices such as sensors, and can control the world around it by adjusting lights, motors, and other actuators. In this class you will learn how and when to use the different types of sensors and how to connect them to the Arduino. Since the external world uses continuous or analog signals and the hardware is digital you will learn how these signals are converted back-and-forth and how this must be considered as you program your device. You'll also learn about the use of Arduino-specific shields and the shields software libraries to interface with the real world. Please note that this course does not include discussion forums.View SyllabusSelect a languageArabicEnglishFrenchGermanItalianRussianSpanishVietnameseptPt[MUSIC] [SOUND] IoT devices have a set of actuators that cause something to happen in the real world. Because IoT devices have to do something, have to have some output, right? And the output goes to actuators and they cause some event in the real world. Now, this event in the real world might be as simple as putting a message on a screen, right. But it could be more sophisticated than that. Basically, actuators are the outputs of the IoT device. So, could be visual, maybe it's a LED, or set of LEDs, lights go off and on. LCD, liquid crystal display, monitor, right? All these things are output devices, and are actuators. Audio, so maybe it's a buzzer or a speaker, so it can make sounds of some kind. Motion, so they can cause motion. So maybe one of the actuators is a motor, that's a common thing, to move something in a physical world. A valve, or a pump to move water or some kind of liquid, to let them pass through a pipe or something like that. Tactile, so, I don't know if you'd call this tactile, but heating and cooling. You can turn on an air conditioner, like in this room, the HVAC in the room. Those are actuators. To the whole control system, if you talk about the HVAC system in this building, the control system's inputs and outputs, its outputs are gonna be heating and cooling units. So, actuators are just devices that do something in the real world. Now, the simplest type of actuation you can have [COUGH] is what I'll call on-off actuation or power actuation. And all you're doing is controlling the power, the only control that you have with this device is power. Now this is very simplistic control. So even complicated actuators can be controlled via power. Minimal control, but you can do something via power. So LEDs, light emitting diodes, you can just turn them off and on. Now you can be more sophisticated about that. You can make them brighter or darker and all that, but you don't have to. You can just say off, on. You can control them in this digital way. A buzzer. You can make it buzz or not buzz. A monitor, you can power it on or off. Now there are all kinds of devices like that. Basically all devices, you can give, you could just control them through power, on, off. Now this, for complicated actuators, this doesn't use the full potential of the actuator. Meaning like with a monitor. With a monitor you can put up messages on there, draw pictures on there, all kinds of sophisticated things. But if you're doing on-off actuation, all you can do is turn it off and on. So you're controlling it but in a minimal way. With an LED. LED off and on is often enough, but you could make it dimmer or brighter. But with on-off actuation, that's not possible. So this is one way to control an actuator, just through power. On-off control may be all that you need. It depends on the application. Maybe all you need it to turn your LED off or on, in which case on-off actuation is just fine. Lights in a classroom, yes, so like in my office when you walk into the room, the light sensor turns the lights on. And it doesn't set the lights at a certain dimness or brightness or something like that, it's that either they're all on or all off. So it's sufficient. Also, air conditioning, like HVAC systems. Typically, like in my office, the air is on or it's off. It doesn't get in between. So that's mostly satisfactory. One thing to worry about or to be aware of when you're actuating something and especially in this power mode, is to think about the current limits of the device, of both devices on both sides, so your micro controller and your actual actuator. Think about the current limits. So for instance, an LED, typical LED might only be able to handle 20 milliamps, so you cannot drive it with more than 20 milliamps without hurting it. So you got to make sure somehow that that it only is driven with 20 milliamps. So for instance, putting in an appropriate resistor in series with the LED will, using V equals IR, you can put the right size resistor to make sure the current never exceeds a certain threshold. Now you also have to think about current limits on the other side, on the supply side. So the Arduino, regular Arduino pins or Arduino Uno, regular pins besides the power and ground, the power pin, rather. Regular pins can only supply 40 milliamps. So if you are driving something that needs more than 40 milliamps you may have a problem. So for instance, if you got a motor that request 50 amperes, then 40 milliamps is clearly not enough. And I say 15 amperes because I think about my quad copter, and those motors can take 10 amperes, 15 maybe. They require a lot of power and the Arduino would never be able to supply that level of power. So in a situation like that, the Arduino can't supply it, so you need some other power supply. So like on a quad-copter, there's a big fat battery on the bottom, and that is the power supply. And my Arduino that I use to drive it, to drive the motors. The Arduino doesn't actually directly feed power to the motor. Instead, the Arduino controls the switch between the battery, the big battery, and the motor. So it controls access to the power in that sense. And we'll talk more in detail about this in future slides. But, [COUGH] so you gotta be aware of these current limits. The Arduino itself can only supply a certain amount of current. So, if you need more than that then you need an alternate power supply. The device that you are actuating, say a LED, might only be able to take a certain amount of current. And you've got to make sure the Arduino or whatever device it is that drives it, can't supply more current than is necessary, than it can take. Thank you. >> [MUSIC] In Module 1, we introduced the concept of the Internet of Things at a high level, defining the term and outlining its implications. In this module we explore some of the details involved in the design and implementation of IoT devices. Unlike traditional computer-based systems, IoT devices are "embedded" within other devices in order to provide enhanced functionality without exposing the user to the complexities of a computer. The users interact with the device in a natural way, similar to their interactions with any other objects in the world. In this way, an embedded system has an interface that conforms to the expectations and needs of the users. Establishing a natural interface requires that the embedded system interface with the physical world directly through sensors, which read the state of the world, and actuators, which change the state of the world. In this module we will discuss the structure of embedded systems and describe these interactions with the physical world. Download Guide for Authors in PDF Sensors & Actuators, B: Chemical is an interdisciplinary journal dedicated to publishing research and development in the field of chemical sensors and biosensors, chemical actuators and analytical microsystems. The journal aims to promote original works that demonstrate significant progress beyond the current state of the art in these fields along with applicability to solve meaningful analytical problems. Review articles may only be submitted upon invitation from an Editor of the journal.The journal aims to publish works that are supported by experimental results and as such purely theoretical works are not accepted. The analytical performance in all analytical parameters needs to be reported and critically compared with the state of the art. Sensing applications will be considered only if they refer to analytically challenging complex samples and are properly validated.The scope of the journal encompasses, but is not restricted to, the following areas:• Novel chemical sensing and biosensing concepts, mechanisms and detection principles• Development of chemical sensors and biosensors• Fabrication technology of chemical sensors, biosensors, chip-based detection devices and chemical actuators• Chemical actuators including soft actuators, micro- and nanomotors, microfluidic components• Photonic and biophotonic sensors and chemical sensing systems• Lab-on-a-chip, Micro Total Analysis Systems (μTAS) and other biochips and microarray systems• Sensor and sensor-array chemometricsReports on new materials, chemical components and fabrication technologies claimed to be relevant to chemical sensing and actuation will be considered for publication only if an immediate application in that respect is presented or it presents in a novel concept or mechanism. Aims and Scope Sensors & Actuators, B: Chemical is an interdisciplinary journal dedicated to publishing research and development in the field of chemical sensors and biosensors, chemical actuators and analytical microsystems. The journal aims to promote original works that demonstrate significant progress beyond the current state of the art in these fields along with applicability to solve meaningful analytical problems. Review articles may only be submitted upon invitation from an Editor of the journal. The journal aims to publish works that are supported by experimental results and as such purely theoretical works are not accepted. The analytical performance in all analytical parameters needs to be reported and critically compared with the state of the art. Sensing applications will be considered only if they refer to analytically challenging complex samples and are properly validated. The scope of the journal encompasses, but is not restricted to, the following areas: • Novel chemical sensing and biosensing concepts, mechanisms and detection principles • Development of chemical sensors and biosensors • Fabrication technology of chemical sensors, biosensors, chip-based detection devices and chemical actuators • Chemical actuators including soft actuators, micro- and nanomotors, microfluidic components • Photonic and biophotonic sensors and chemical sensing systems • Lab-on-a-chip, Micro Total Analysis Systems (μTAS) and other biochips and microarray systems • Sensor and sensor-array chemometrics Reports on new materials, chemical components and fabrication technologies claimed to be relevant to chemical sensing and actuation will be considered for publication only if an immediate application in that respect is presented or it presents in a novel concept or mechanism. Types of paper Sensors and Actuators B: Chemical, publishes full length research papers and review articles, and short communications. Review articles may only be submitted upon invitation from an Editor of the journal. Direct submission of unsolicited review articles without previous permission of an Editor will not be considered for publication. Authors are required to detail the invitation in their Covering Letter at submission stages, including the name of the inviting Editor. Full length papers should in general not exceed 5000 words or about 12 printed pages including tables and diagrams. Short communications should not exceed 2000 words or 4 printed pages. For all contributions the acceptance criteria are quality, originality, and scientific and technological relevance to the field. An adequate referencing to the state-of-the-art is essential. Submission checklist You can use this list to carry out a final check of your submission before you send it to the journal for review. Please check the relevant section in this Guide for Authors for more details. Ensure that the following items are present:One author has been designated as the corresponding author with contact details:• E-mail address• Full postal address All necessary files have been uploaded:Manuscript:• Include keywords• All figures (include relevant captions)• All tables (including titles, description, footnotes)• Ensure all figure and table citations in the text match the files provided• Indicate clearly if color should be used for any figures in printGraphical Abstracts / Highlights files (where applicable)Supplemental files (where applicable)Further considerations• Manuscript has been 'spell checked' and 'grammar checked'• All references mentioned in the Reference List are cited in the text, and vice versa• Permission has been obtained for use of copyrighted material from other sources (including the Internet)• A competing interests statement is provided, even if the authors have no competing interests to declare• Journal policies detailed in this guide have been reviewed• Referee suggestions and contact details provided, based on journal requirements For further information, visit our Support Center. Ethics in publishing Please see our information on Ethics in publishing. Declaration of competing interest All authors must disclose any financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work. Examples of potential conflicts of interest include employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/registrations, and grants or other funding. Authors should create a declaration of competing interest statement using this tool and upload to the submission system at the Attach Files step. Note: Please do not convert the .docx template to another file type. Author signatures are not required. Submission declaration and verification Submission of an article implies that the work described has not been published previously (except in the form of an abstract, a published lecture or academic thesis, see 'Multiple, redundant or concurrent publication' for more information), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. To verify originality, your article may be checked by the originality detection service Crossref Similarity Check. Use of inclusive language Inclusive language acknowledges diversity, conveys respect to all people, is sensitive to differences, and promotes equal opportunities. Content should make no assumptions about the beliefs or commitments of any reader; contain nothing which might imply that one individual is superior to another on the grounds of age, gender, race, ethnicity, culture, sexual orientation, disability or health condition; and use inclusive language throughout. Authors should ensure that writing is free from bias, stereotypes, slang, reference to dominant culture and/or cultural assumptions. We advise to seek gender neutrality by using plural nouns ("clinicians, patients/clients") as default/wherever possible to avoid using "he, she," or "he/she." We recommend avoiding the use of descriptors that refer to personal attributes such as age, gender, race, ethnicity, culture, sexual orientation, disability or health condition unless they are relevant and valid. These guidelines are meant as a point of reference to help identify appropriate language but are by no means exhaustive or definitive. Author contributions For transparency, we encourage authors to submit an author statement file outlining their individual contributions to the paper using the relevant CRediT roles: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Roles/Writing - original draft; Writing - review & editing. Authorship statements should be formatted with the names of authors first and CRediT role(s) following. More details and an example Changes to authorship Authors are expected to consider carefully the list and order of authors before submitting their manuscript and provide the definitive list of authors at the time of the original submission. Any addition, deletion or rearrangement of author names in the authorship list should be made only before the manuscript has been accepted and only if approved by the journal Editor. To request such a change, the Editor must receive the following from the corresponding author: (a) the reason for the change in author list and (b) written confirmation (e-mail, letter) from all authors that they agree with the addition, removal or rearrangement. In the case of addition or removal of authors, this includes confirmation from the author being added or removed.Only in exceptional circumstances will the Editor consider the addition, deletion or rearrangement of authors after the manuscript has been accepted. While the Editor considers the request, publication of the manuscript will be suspended. If the manuscript has already been published in an online issue, any requests approved by the Editor will result in a corrigendum. Article transfer service This journal is part of our Article Transfer Service. This means that if the Editor feels your article is more suitable in one of our other participating journals, then you may be asked to consider transferring the article to one of those. If you agree, your article will be transferred automatically on your behalf with no need to reformat. Please note that your article will be reviewed again by the new journal. More information. Copyright Upon acceptance of an article, authors will be asked to complete a 'Journal Publishing Agreement' (see more information on this). An e-mail will be sent to the corresponding author confirming receipt of the manuscript together with a 'Journal Publishing Agreement' form or a link to the online version of this agreement.Subscribers may reproduce tables of contents or prepare lists of articles including abstracts for internal circulation within their institutions. Permission of the Publisher is required for resale or distribution outside the institution and for all other derivative works, including compilations and translations. If excerpts from other copyrighted works are included, the author(s) must obtain written permission from the copyright owners and credit the source(s) in the article. Elsevier has preprinted forms for use by authors in these cases.For gold open access articles: Upon acceptance of an article, authors will be asked to complete a 'License Agreement' (more information). Permitted third party reuse of gold open access articles is determined by the author's choice of user license.Author rightsAs an author you (or your employer or institution) have certain rights to reuse your work. More information. Elsevier supports responsible sharing Find out how you can share your research published in Elsevier journals. Role of the funding source You are requested to identify who provided financial support for the conduct of the research and/or preparation of the article and to briefly describe the role of the sponsor(s), if any, in study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication. If the funding source(s) had no such involvement then this should be stated. Open access Please visit our Open Access page for more information. Elsevier Researcher Academy Researcher Academy is a free e-learning platform designed to support early and mid-career researchers throughout their research journey. The "Learn" environment at Researcher Academy offers several interactive modules, webinars, downloadable guides and resources to guide you through the process of writing for research and going through peer review. Feel free to use these free resources to improve your submission and navigate the publication process with ease. Language (usage and editing services) Please write your text in good English (American or British usage is accepted, but not a mixture of these). Authors who feel their English language manuscript may require editing to eliminate possible grammatical or spelling errors and to conform to correct scientific English may wish to use the English Language Editing service available from Elsevier's Author Services. Submission Our online submission system guides you stepwise through the process of entering your article details and uploading your files. The system converts your article files to a single PDF file used in the peer-review process. Editable files (e.g., Word, LaTeX) are required to typeset your article for final publication. All correspondence, including notification of the Editor's decision and requests for revision, is sent by e-mail.Please sunmit your article via Referees Authors are required to submit the names, addresses and e-mail addresses of five potential reviewers who could objectively review their manuscripts if asked to do so by the journal editors. At least three of the five suggestions should be working in a different country than the authors. The editor retains the sole right to decide whether or not the suggested reviewers are used. Please note that if no reviewer names are submitted, publication of your manuscript may be delayed. Queries For questions about the editorial process (including the status of manuscripts under review) or for technical support on submissions, please visit our Support Center. Peer review This journal operates a single anonymized review process. All contributions will be initially assessed by the editor for suitability for the journal. Papers deemed suitable are then typically sent to a minimum of two independent expert reviewers to assess the scientific quality of the paper. The Editor is responsible for the final decision regarding acceptance or rejection of articles. The Editor's decision is final. Editors are not involved in decisions about papers which they have written themselves or have been written by family members or colleagues or which relate to products or services in which the editor has an interest. Any such submission is subject to all of the journal's usual procedures, with peer review handled independently of the relevant editor and their research groups. More information on types of peer review. Use of word processing software It is important that the file be saved in the native format of the word processor used. The text should be in single-column format. Keep the layout of the text as simple as possible. Most formatting codes will be removed and replaced on processing the article. In particular, do not use the word processor's options to justify text or to hyphenate words. However, do use bold face, italics, subscripts, superscripts etc. When preparing tables, if you are using a table grid, use only one grid for each individual table and not a grid for each row. If no grid is used, use tabs, not spaces, to align columns. The electronic text should be prepared in a way very similar to that of conventional manuscripts (see also the Guide to Publishing with Elsevier). Note that source files of figures, tables and text graphics will be required whether or not you embed your figures in the text. See also the section on Electronic artwork. To avoid unnecessary errors you are strongly advised to use the 'spell-check' and 'grammar-check' functions of your word processor. Article structure Subdivision - numbered sections Divide your article into clearly defined and numbered sections. Subsections should be numbered 1.1 (then 1.1.1, 1.1.2, ...), 1.2, etc. (the abstract is not included in section numbering). Use this numbering also for internal cross-referencing: do not just refer to 'the text'. Any subsection may be given a brief heading. Each heading should appear on its own separate line. Introduction State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results. Material and methods Provide sufficient details to allow the work to be reproduced by an independent researcher. Methods that are already published should be summarized, and indicated by a reference. If quoting directly from a previously published method, use quotation marks and also cite the source. Any modifications to existing methods should also be described. Results Results should be clear and concise. Discussion This should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature. Conclusions The main conclusions of the study may be presented in a short Conclusions section, which may stand alone or form a subsection of a Discussion or Results and Discussion section. Appendices If there is more than one appendix, they should be identified as A, B, etc. Formulae and equations in appendices should be given separate numbering: Eq. (A.1), Eq. (A.2), etc.; in a subsequent appendix, Eq. (B.1) and so on. Similarly for tables and figures: Table A.1; Fig. A.1, etc. Essential title page information • Title. Concise and informative. Titles are often used in information-retrieval systems. Avoid abbreviations and formulae where possible.• Author names and affiliations. Please clearly indicate the given name(s) and family name(s) of each author and check that all names are accurately spelled. You can add your name between parentheses in your own script behind the English transliteration. Present the authors' affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lower-case superscript letter immediately after the author's name and in front of the appropriate address. Provide the full postal address of each affiliation, including the country name and, if available, the e-mail address of each author.• Corresponding author. Clearly indicate who will handle correspondence at all stages of refereeing and publication, also post-publication. This responsibility includes answering any future queries about Methodology and Materials. Ensure that the e-mail address is given and that contact details are kept up to date by the corresponding author.• Present/permanent address. If an author has moved since the work described in the article was done, or was visiting at the time, a 'Present address' (or 'Permanent address') may be indicated as a footnote to that author's name. The address at which the author actually did the work must be retained as the main, affiliation address. Superscript Arabic numerals are used for such footnotes. Highlights Highlights are mandatory for this journal as they help increase the discoverability of your article via search engines. They consist of a short collection of bullet points that capture the novel results of your research as well as new methods that were used during the study (if any). Please have a look at the examples here: example Highlights. Highlights should be submitted in a separate editable file in the online submission system. Please use 'Highlights' in the file name and include 3 to 5 bullet points (maximum 85 characters, including spaces, per bullet point). Abstract A concise and factual abstract is required. The abstract should state briefly the purpose of the research, the principal results and major conclusions. An abstract is often presented separately from the article, so it must be able to stand alone. For this reason, References should be avoided, but if essential, then cite the author(s) and year(s). Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself. Keywords Immediately after the abstract, provide a maximum of 6 keywords, using American spelling and avoiding general and plural terms and multiple concepts (avoid, for example, 'and', 'of'). Be sparing with abbreviations: only abbreviations firmly established in the field may be eligible. These keywords will be used for indexing purposes. Abbreviations Define abbreviations that are not standard in this field in a footnote to be placed on the first page of the article. Such abbreviations that are unavoidable in the abstract must be defined at their first mention there, as well as in the footnote. Ensure consistency of abbreviations throughout the article. Acknowledgements Collate acknowledgements in a separate section at the end of the article before the references and do not, therefore, include them on the title page, as a footnote to the title or otherwise. List here those individuals who provided help during the research (e.g., providing language help, writing assistance or proof reading the article, etc.). Formatting of funding sources List funding sources in this standard way to facilitate compliance to funder's requirements:Funding: This work was supported by the National Institutes of Health [grant numbers xxxx, yyyy]; the Bill & Melinda Gates Foundation, Seattle, WA [grant number zzzz]; and the United States Institutes of Peace [grant number aaaa].It is not necessary to include detailed descriptions on the program or type of grants and awards. When funding is from a block grant or other resources available to a university, college, or other research institution, submit the name of the institute or organization that provided the funding.If no funding has been provided for the research, please include the following sentence:This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Math formulae Please submit math equations as editable text and not as images. Present simple formulae in line with normal text where possible and use the solidus (/) instead of a horizontal line for small fractional terms, e.g., X/Y. In principle, variables are to be presented in italics. Powers of e are often more conveniently denoted by exp. Number consecutively any equations that have to be displayed separately from the text (if referred to explicitly in the text). Footnotes Footnotes should be used sparingly. Number them consecutively throughout the article. Many word processors can build footnotes into the text, and this feature may be used. Otherwise, please indicate the position of footnotes in the text and list the footnotes themselves separately at the end of the article. Do not include footnotes in the Reference list. Artwork Electronic artwork General points• Make sure you use uniform lettering and sizing of your original artwork. • Embed the used fonts if the application provides that option. • Aim to use the following fonts in your illustrations: Arial, Courier, Times New Roman, Symbol, or use fonts that look similar. • Number the illustrations according to their sequence in the text. • Use a logical naming convention for your artwork files. • Provide captions to illustrations separately. • Size the illustrations close to the desired dimensions of the published version. • Submit each illustration as a separate file.• Ensure that color images are accessible to all, including those with impaired color vision.A detailed guide on electronic artwork is available.You are urged to visit this site; some excerpts from the detailed information are given here.FormatsIf your electronic artwork is created in a Microsoft Office application (Word, PowerPoint, Excel) then please supply 'as is' in the native document format. Regardless of the application used other than Microsoft Office, when your electronic artwork is finalized, please 'Save as' or convert the images to one of the following formats (note the resolution requirements for line drawings, halftones, and line/halftone combinations given below): EPS (or PDF): Vector drawings, embed all used fonts. TIFF (or JPEG): Color or grayscale photographs (halftones), keep to a minimum of 300 dpi. TIFF (or JPEG): Bitmapped (pure black & white pixels) line drawings, keep to a minimum of 1000 dpi. TIFF (or JPEG): Combinations bitmapped line/half-tone (color or grayscale), keep to a minimum of 500 dpi.Please do not: • Supply files that are optimized for screen use (e.g., GIF, BMP, PICT, WPG); these typically have a low number of pixels and limited set of colors; • Supply files that are too low in resolution; • Submit graphics that are disproportionately large for the content. Color artwork Please make sure that artwork files are in an acceptable format (TIFF (or JPEG), EPS (or PDF), or MS Office files) and with the correct resolution. If, together with your accepted article, you submit usable color figures then Elsevier will ensure, at no additional charge, that these figures will appear in color online (e.g., ScienceDirect and other sites) regardless of whether or not these illustrations are reproduced in color in the printed version. For color reproduction in print, you will receive information regarding the costs from Elsevier after receipt of your accepted article. Please indicate your preference for color: in print or online only. Further information on the preparation of electronic artwork. Figure captions Ensure that each illustration has a caption. Supply captions separately, not attached to the figure. A caption should comprise a brief title (not on the figure itself) and a description of the illustration. Keep text in the illustrations themselves to a minimum but explain all symbols and abbreviations used. Tables Please submit tables as editable text and not as images. Tables can be placed either next to the relevant text in the article, or on separate page(s) at the end. Number tables consecutively in accordance with their appearance in the text and place any table notes below the table body. Be sparing in the use of tables and ensure that the data presented in them do not duplicate results described elsewhere in the article. Please avoid using vertical rules and shading in table cells. References Citation in text Please ensure that every reference cited in the text is also present in the reference list (and vice versa). Any references cited in the abstract must be given in full. Unpublished results and personal communications are not recommended in the reference list, but may be mentioned in the text. If these references are included in the reference list they should follow the standard reference style of the journal and should include a substitution of the publication date with either 'Unpublished results' or 'Personal communication'. Citation of a reference as 'in press' implies that the item has been accepted for publication. Reference links Increased discoverability of research and high quality peer review are ensured by online links to the sources cited. In order to allow us to create links to abstracting and indexing services, such as Scopus, CrossRef and PubMed, please ensure that data provided in the references are correct. Please note that incorrect surnames, journal/book titles, publication year and pagination may prevent link creation. When copying references, please be careful as they may already contain errors. Use of the DOI is highly encouraged.A DOI is guaranteed never to change, so you can use it as a permanent link to any electronic article. An example of a citation using DOI for an article not yet in an issue is: VanDecar J.C., Russo R.M., James D.E., Ambeh W.B., Franke M. (2003). Aseismic continuation of the Lesser Antilles slab beneath northeastern Venezuela. Journal of Geophysical Research, . Please note the format of such citations should be in the same style as all other references in the paper. Web references As a minimum, the full URL should be given and the date when the reference was last accessed. Any further information, if known (DOI, author names, dates, reference to a source publication, etc.), should also be given. Web references can be listed separately (e.g., after the reference list) under a different heading if desired, or can be included in the reference list. Data references This journal encourages you to cite underlying or relevant datasets in your manuscript by citing them in your text and including a data reference in your Reference List. Data references should include the following elements: author name(s), dataset title, data repository, version (where available), year, and global persistent identifier. Add [dataset] immediately before the reference so we can properly identify it as a data reference. The [dataset] identifier will not appear in your published article. References in a special issue Please ensure that the words 'this issue' are added to any references in the list (and any citations in the text) to other articles in the same Special Issue. Reference management software Most Elsevier journals have their reference template available in many of the most popular reference management software products. These include all products that support Citation Style Language styles, such as Mendeley. Using citation plug-ins from these products, authors only need to select the appropriate journal template when preparing their article, after which citations and bibliographies will be automatically formatted in the journal's style. If no template is yet available for this journal, please follow the format of the sample references and citations as shown in this Guide. If you use reference management software, please ensure that you remove all field codes before submitting the electronic manuscript. More information on how to remove field codes from different reference management software. Users of Mendeley Desktop can easily install the reference style for this journal by clicking the following link: preparing your manuscript, you will then be able to select this style using the Mendeley plug-ins for Microsoft Word or LibreOffice. Reference formatting There are no strict requirements on reference formatting at submission. References can be in any style or format as long as the style is consistent. Where applicable, author(s) name(s), journal title/book title, chapter title/article title, year of publication, volume number/book chapter and the article number or pagination must be present. Use of DOI is highly encouraged. The reference style used by the journal will be applied to the accepted article by Elsevier at the proof stage. Note that missing data will be highlighted at proof stage for the author to correct. If you do wish to format the references yourself they should be arranged according to the following examples: Reference style Text: Indicate references by number(s) in square brackets in line with the text. The actual authors can be referred to, but the reference number(s) must always be given. Example: '..... as demonstrated [3,6]. Barnaby and Jones [8] obtained a different result ....' List: Number the references (numbers in square brackets) in the list in the order in which they appear in the text. Examples: Reference to a journal publication: [1] J. van der Geer, J.A.J. Hanraads, R.A. Lupton, The art of writing a scientific article, J. Sci. Commun. 163 (2010) 51–59. to a journal publication with an article number: [2] J. van der Geer, J.A.J. Hanraads, R.A. Lupton, 2018. The art of writing a scientific article. Heliyon. 19, e00205. to a book: [3] W. Strunk Jr., E.B. White, The Elements of Style, fourth ed., Longman, New York, 2000. Reference to a chapter in an edited book: [4] G.R. Mettam, L.B. Adams, How to prepare an electronic version of your article, in: B.S. Jones, R.Z. Smith (Eds.), Introduction to the Electronic Age, E-Publishing Inc., New York, 2009, pp. 281–304.Reference to a website:[5] Cancer Research UK, Cancer statistics reports for the UK. 2003 (accessed 13 March 2003).Reference to a dataset:[dataset] [6] M. Oguro, S. Imahiro, S. Saito, T. Nakashizuka, Mortality data for Japanese oak wilt disease and surrounding forest compositions, Mendeley Data, v1, 2015. to software:[7] E. Coon, M. Berndt, A. Jan, D. Svyatsky, A. Atchley, E. Kikinzon, D. Harp, G. Manzini, E. Shelef, K. Lipnikov, R. Garimella, C. Xu, D. Moulton, S. Karra, S. Painter, E. Jafarov, S. Molins, Advanced Terrestrial Simulator (ATS) v0.88 (Version 0.88), Zenodo, March 25, 2020. . Journal abbreviations source Journal names should be abbreviated according to the List of Title Word Abbreviations. Video Elsevier accepts video material and animation sequences to support and enhance your scientific research. Authors who have video or animation files that they wish to submit with their article are strongly encouraged to include links to these within the body of the article. This can be done in the same way as a figure or table by referring to the video or animation content and noting in the body text where it should be placed. All submitted files should be properly labeled so that they directly relate to the video file's content. In order to ensure that your video or animation material is directly usable, please provide the file in one of our recommended file formats with a preferred maximum size of 150 MB per file, 1 GB in total. Video and animation files supplied will be published online in the electronic version of your article in Elsevier Web products, including ScienceDirect. Please supply 'stills' with your files: you can choose any frame from the video or animation or make a separate image. These will be used instead of standard icons and will personalize the link to your video data. For more detailed instructions please visit our video instruction pages. Note: since video and animation cannot be embedded in the print version of the journal, please provide text for both the electronic and the print version for the portions of the article that refer to this content. Data visualization Include interactive data visualizations in your publication and let your readers interact and engage more closely with your research. Follow the instructions here to find out about available data visualization options and how to include them with your article. Supplementary material Supplementary material such as applications, images and sound clips, can be published with your article to enhance it. Submitted supplementary items are published exactly as they are received (Excel or PowerPoint files will appear as such online). Please submit your material together with the article and supply a concise, descriptive caption for each supplementary file. If you wish to make changes to supplementary material during any stage of the process, please make sure to provide an updated file. Do not annotate any corrections on a previous version. Please switch off the 'Track Changes' option in Microsoft Office files as these will appear in the published version. Research data This journal encourages and enables you to share data that supports your research publication where appropriate, and enables you to interlink the data with your published articles. Research data refers to the results of observations or experimentation that validate research findings. To facilitate reproducibility and data reuse, this journal also encourages you to share your software, code, models, algorithms, protocols, methods and other useful materials related to the project.Below are a number of ways in which you can associate data with your article or make a statement about the availability of your data when submitting your manuscript. If you are sharing data in one of these ways, you are encouraged to cite the data in your manuscript and reference list. Please refer to the "References" section for more information about data citation. For more information on depositing, sharing and using research data and other relevant research materials, visit the research data page. Data linking If you have made your research data available in a data repository, you can link your article directly to the dataset. Elsevier collaborates with a number of repositories to link articles on ScienceDirect with relevant repositories, giving readers access to underlying data that gives them a better understanding of the research described.There are different ways to link your datasets to your article. When available, you can directly link your dataset to your article by providing the relevant information in the submission system. For more information, visit the database linking page.For supported data repositories a repository banner will automatically appear next to your published article on ScienceDirect.In addition, you can link to relevant data or entities through identifiers within the text of your manuscript, using the following format: Database: xxxx (e.g., TAIR: AT1G01020; CCDC: 734053; PDB: 1XFN). Mendeley Data This journal supports Mendeley Data, enabling you to deposit any research data (including raw and processed data, video, code, software, algorithms, protocols, and methods) associated with your manuscript in a free-to-use, open access repository. During the submission process, after uploading your manuscript, you will have the opportunity to upload your relevant datasets directly to Mendeley Data. The datasets will be listed and directly accessible to readers next to your published article online.For more information, visit the Mendeley Data for journals page. Data in Brief You have the option of converting any or all parts of your supplementary or additional raw data into a data article published in Data in Brief. A data article is a new kind of article that ensures that your data are actively reviewed, curated, formatted, indexed, given a DOI and made publicly available to all upon publication (watch this video describing the benefits of publishing your data in Data in Brief). You are encouraged to submit your data article for Data in Brief as an additional item directly alongside the revised version of your manuscript. If your research article is accepted, your data article will automatically be transferred over to Data in Brief where it will be editorially reviewed, published open access and linked to your research article on ScienceDirect. Please note an open access fee is payable for publication in Data in Brief. Full details can be found on the Data in Brief website. Please use this template to write your Data in Brief data article. MethodsX You have the option of converting relevant protocols and methods into one or multiple MethodsX articles, a new kind of article that describes the details of customized research methods. Many researchers spend a significant amount of time on developing methods to fit their specific needs or setting, but often without getting credit for this part of their work. MethodsX, an open access journal, now publishes this information in order to make it searchable, peer reviewed, citable and reproducible. Authors are encouraged to submit their MethodsX article as an additional item directly alongside the revised version of their manuscript. If your research article is accepted, your methods article will automatically be transferred over to MethodsX where it will be editorially reviewed. Please note an open access fee is payable for publication in MethodsX. Full details can be found on the MethodsX website. Please use this template to prepare your MethodsX article. Data statement To foster transparency, we encourage you to state the availability of your data in your submission. This may be a requirement of your funding body or institution. If your data is unavailable to access or unsuitable to post, you will have the opportunity to indicate why during the submission process, for example by stating that the research data is confidential. The statement will appear with your published article on ScienceDirect. For more information, visit the Data Statement page. Online proof correction To ensure a fast publication process of the article, we kindly ask authors to provide us with their proof corrections within two days. Corresponding authors will receive an e-mail with a link to our online proofing system, allowing annotation and correction of proofs online. The environment is similar to MS Word: in addition to editing text, you can also comment on figures/tables and answer questions from the Copy Editor. Web-based proofing provides a faster and less error-prone process by allowing you to directly type your corrections, eliminating the potential introduction of errors.If preferred, you can still choose to annotate and upload your edits on the PDF version. All instructions for proofing will be given in the e-mail we send to authors, including alternative methods to the online version and PDF.We will do everything possible to get your article published quickly and accurately. Please use this proof only for checking the typesetting, editing, completeness and correctness of the text, tables and figures. Significant changes to the article as accepted for publication will only be considered at this stage with permission from the Editor. It is important to ensure that all corrections are sent back to us in one communication. Please check carefully before replying, as inclusion of any subsequent corrections cannot be guaranteed. Proofreading is solely your responsibility. Offprints The corresponding author will, at no cost, receive a customized Share Link providing 50 days free access to the final published version of the article on ScienceDirect. The Share Link can be used for sharing the article via any communication channel, including email and social media. For an extra charge, paper offprints can be ordered via the offprint order form which is sent once the article is accepted for publication. Both corresponding and co-authors may order offprints at any time via Elsevier's Author Services. Corresponding authors who have published their article gold open access do not receive a Share Link as their final published version of the article is available open access on ScienceDirect and can be shared through the article DOI link. Visit the Elsevier Support Center to find the answers you need. Here you will find everything from Frequently Asked Questions to ways to get in touch.You can also check the status of your submitted article or find out when your accepted article will be published.