EXPERIENCES FROM AN ARDUINO PROGRAMMING COURSE FOR TEACHERS

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The authors

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- 20+ years of teaching experience at the University
- 15 years at the secondary school
- Courses for teachers and industry
- Software projects for the University and other customers

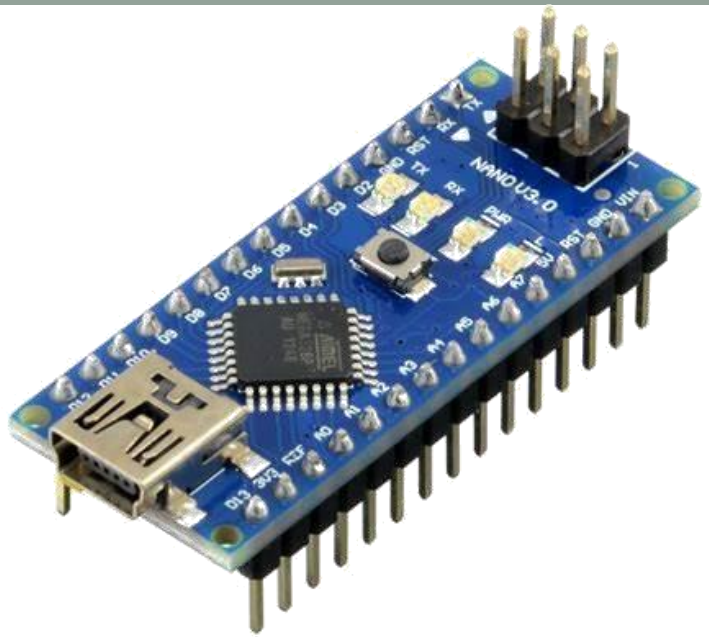
Motivation

- Introduced an undergraduate course on Arduino and IoT programming at the Faculty of Science, Department of Mathematics and Informatics
- Students have little to no experience with electronics
- In Computer Organization and Architecture they learn about the operation of digital computers and assembly
- However the IT industry in Novi Sad offers jobs in IoT
- Our course connects CO&A with high level programming and also offers introduction to solving real life problems
- The main challenge is to deliver a completed product

What is Arduino?

- Open-source electronics platform based on affordable and simple hardware
- Microcontroller CPU with built-in memory and I/O ports
- Programmed in C++ or other languages
- Arduino IDE
- Arduino framework
- Software libraries
- Hardware devices and add-on boards

Hardware specs



- Arduino Uno
- 8-bit Atmel AT328 @ 16MHz
- 32KB program Flash
- 2KB RAM
- 1KB EEPROM
- 23 general purpose I/O pins, some with PWM
- 6 channel A/D converter
- UART, SPI and I2C interfaces

Arduino-based learning kits

- Affordable and available in many configurations
- Individual components can be obtained directly from the source at lower prices

Target audience

- We developed a curriculum on C++ programming for Arduino with introduction to electronics
- Target audience: elementary and middle school teachers
- Three 16-hour courses held in 2018
- 47 participants, 23 male and 24 female
- 8 elementary school teachers
- 39 middle school teachers
- 16 participants with 8-15 years of experience
- 19 participants with 16-25 years of experience

Course outline

- Analog and digital electronics
- Arduino hardware and related devices
- Arduino software
- C++ programming
- Specific C++ topics: pointers and memory access
- Advanced topics: registers, interrupts, multitasking, interprocess communication, serial interfaces
- Encapsulation, abstraction and sepraration of concerns: enums, structs, clases, drivers, libraries

Aims and goals

- **Demistify working principles of digital technology**
  (finally explain what those ones and zeros are all about)
- **Teach basics of machine-level programming**
  (as opposed to high-level JavaScript frameworks)
- **Emphasize the importance of algorithmic thinking**
  (one thing at a time)
- **Teach patience and planning**
  (instead of immediately typing in code)
- **Explain the evolution of computers**
  (did you know that keyboard is considered a ’luxury’?)

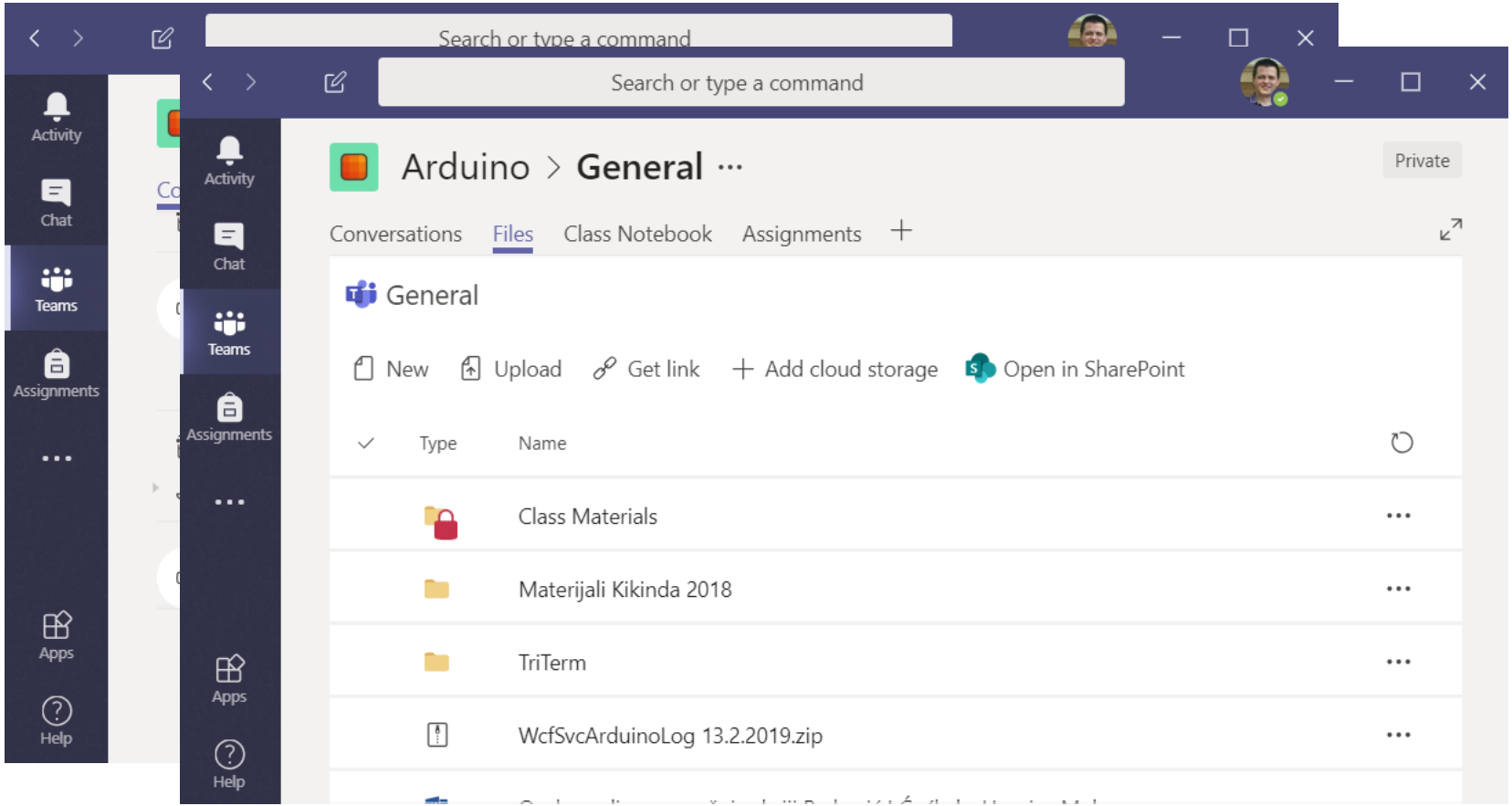
Prerequisites

- Some programming experience is needed
- Basic knowledge of electronics -and mathematics
- A complete shift in programming paradigm is necessary as soon as non-trivial examples are introduced
- Smart houses? Intelligent robots?
  Yes, but that will have to wait...
  ... at least until you learn how to read a keyboard!
- A modest computer will do for the Arduino IDE (Windows, Linux, MacOS)

Office 365 for content delivery

- Teaching materials prepared beforehand (PDF)
- Circuit diagrams
- Example programs
- References to relevant web sites

- Office 365 logins for all participants
- Microsoft Teams for screen sharing and communication
- SharePoint site for assignment collection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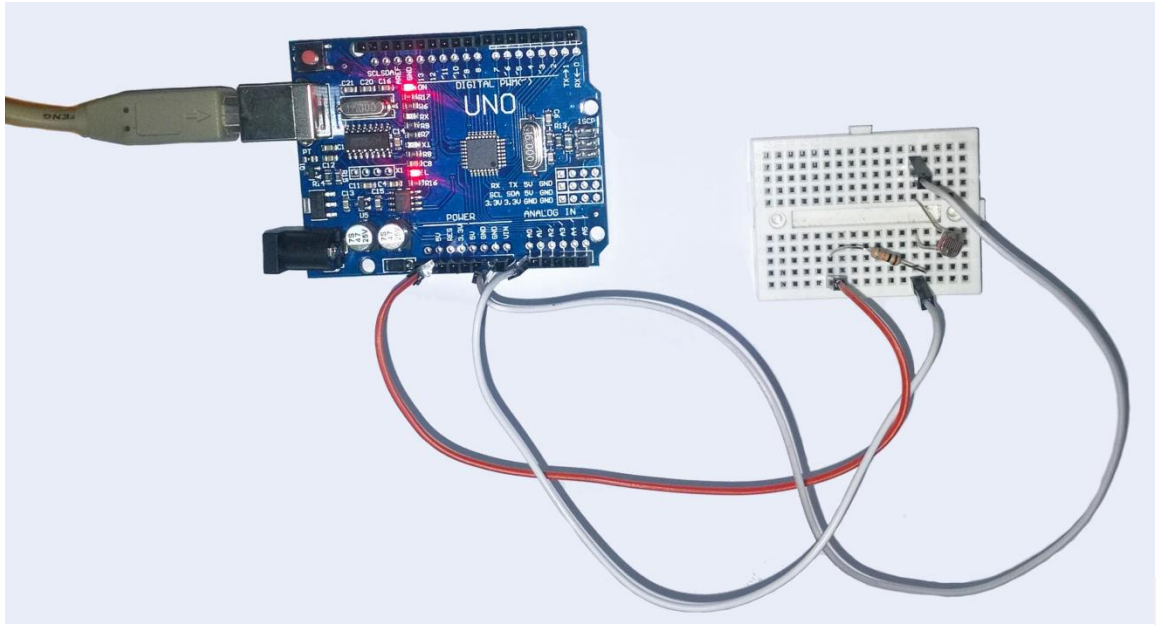
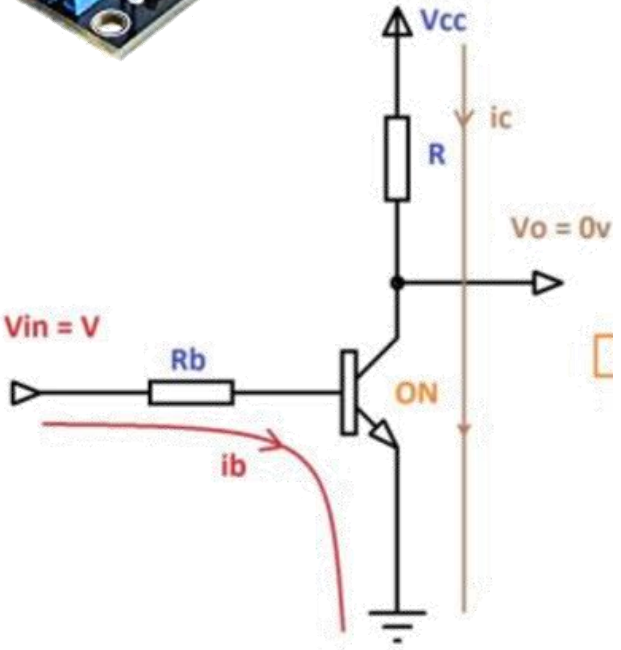
Basic examples

- Blinking LED
- Light sensor
- Buzzer
- Digital input
- Traffic light
- Potentiometer
- Serial data



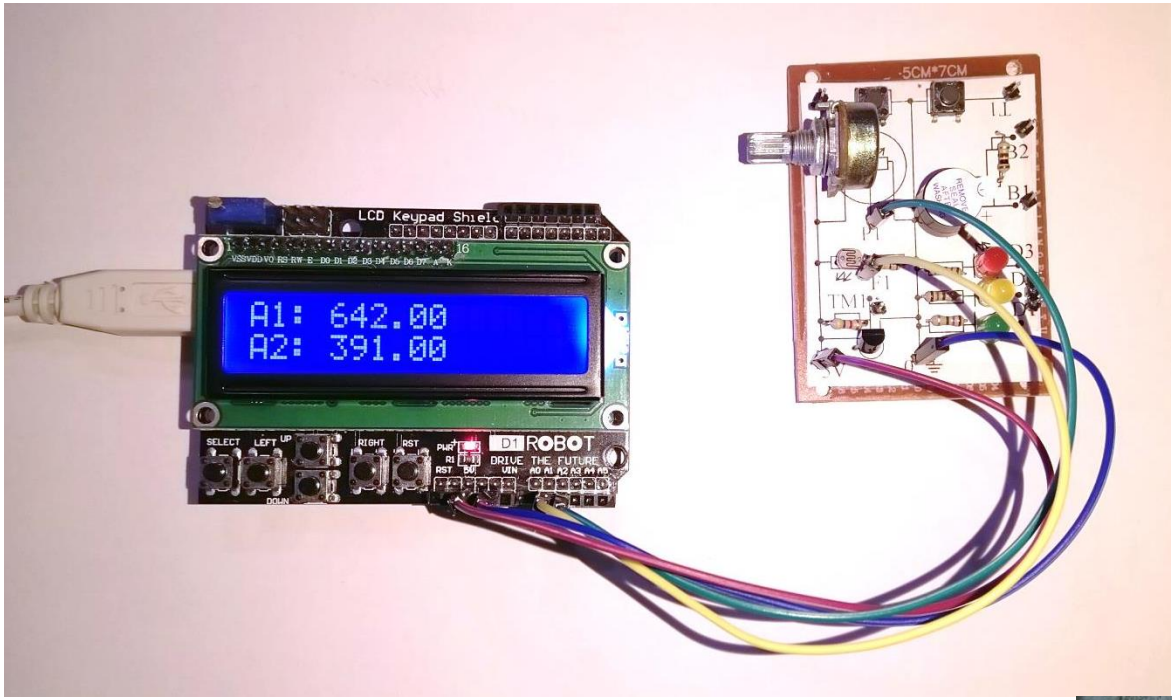
Example – light sensor

- setup()
  - Initialize the light sensor
  - Initalize the relay
- loop()
  - Read the light sensor value
  - Check if the value is over a threshold
  - If yes, turn the relay on
  - If no, turn the relay off
  - Optionally, display status on a LED or LCD
  - Wait a short time
  - Repeat



Complex examples

- Libraries
- LCD screens
- Keypad reading
- Countdown timers
- State machines
- User interface considerations
- RTOS



Gradual release of responsibility

- From „I do“ to „We do“ and finally „You do“
- First the teacher is demonstrating the desired outcome
- Then the teacher and the pupils collaborate
- Finally the pupils work independently
- Individual work in pairs and small groups

- Requires independence, maturity and self-confidence
- Knowledge of the English language is a must
- Browsing the Web and filtering the results

Experiences from the course

- The teachers were well motivated
- The course alternates between lectures and exercises
- We prepared Arduino kits for hands-on exercises
- Solutions to problems were prepared beforehand or demonstrated after the exercises and handed out later
- Depth-first approach: focusing on important parts
- We assisted during the exercises

Observations

- Most teachers were satisfied with the topics and scope of the course
- Some found C++ difficult
- For some, the programming model was counter-intuitive because it doesn't follow the linear program structure
- Abstractions are not visible from the code
- Problems with wires falling out, reversed polarities and libraries for hardware components
- No debugger!

Observations (cont'd)

- Some struggling with elementary calculations (current, resistance and similar)
- Difficulties compiling the known parts into a working whole
- Debugging the software is difficult, but not impossible, thanks to Serial.print
- Debugging the hardware is more difficult

- Real life problems do not conform to carefully prepared classroom exercises! („the numbers aren't nice")

Conclusions

- Most of the teachers are competent and curious enough about Arduino and the possibilities it brings
- However some had difficulties adapting to a different programming model and abstractions which are not explicitly formulated in hardware or software
- Fear and lack of confidence hinder their performance

- Arduino connects real life to the classroom, but doesn’t shield the user from the complexities of computers

- Plan for failure and learn from it

Conclusions (cont'd)

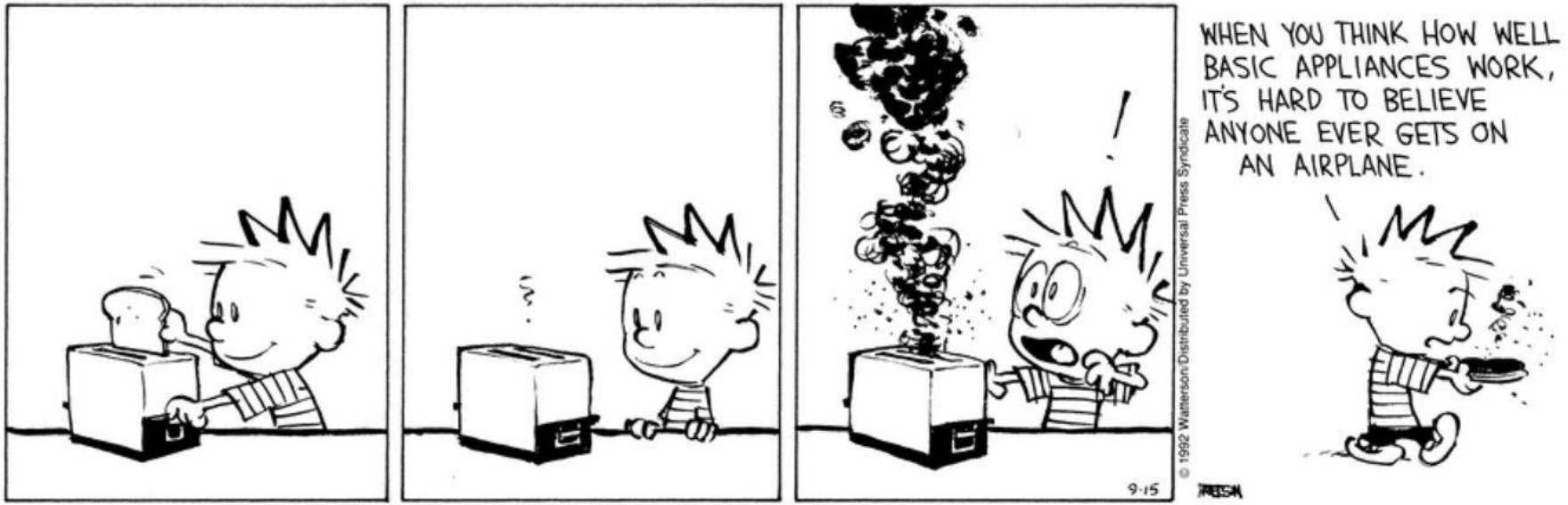
- Attention should be devoted to confidence building exercises for teachers
- Lifelong learning is not just a catchy phrase, it is a necessity
- Failed exercises should not be feared, they should be planned for and learned from
- Curiosity is a positive trait
- Strong emphasis on responsibility
- Double the hours or halve the curriculums!

Plans for the future

- Develop more learning materials
  - a book
  - Videos
  - Office 365 resources

- Teach software project management in practice
- Connections to IT industry, joint projects for students
- Academic work that stems from professional work
- Networking

Calvin and Hobbes by Bill Watterson



Thank you!