A Survey and Taxonomy of Electronics Toolkits for Interactive and Ubiquitous Device Prototyping

MANNU LAMBRICHTS

INTRODUCTION

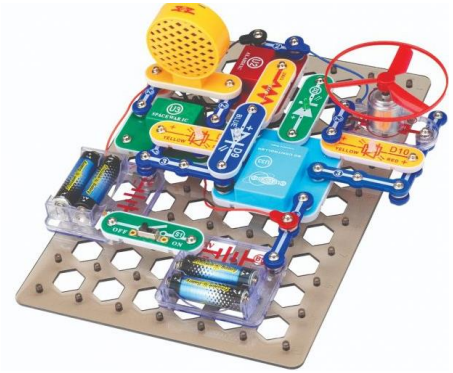
- General-purpose computing devices like personal computers, tablets and smartphones.
- Developing embedded solution based on custom microcontroller circuit.
- Hardware development systems such as Arduino and Phidgets.
- Processor speed, amount of memory and nature of supported input and output modalities are different.
- Several toolkits require skills in either programming or electronics.
- Sometimes the resulting prototype can run standalone.
- Some toolkits are generic in nature while others are particularly suited for building specific types of prototype.

Arduino

Custom MCU

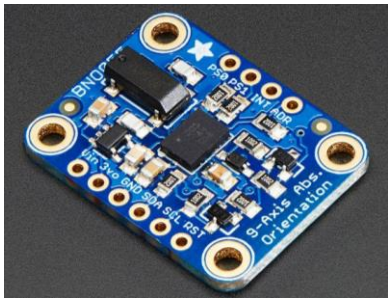
APPROACHES TO ELECTRONICS PROTOTYPING

- Type 1 -Prototyping with Discrete Components
  - It would be difficult to build a copy of a circuit
  - Requires significant knowledge of electronics
- Type 2a: Integrated Microcontroller Development Boards
  - any given design typically requires integration with components that are not present on the ready-made MCU
- Type 2b: Breakout Boards and Wireless Modules
  - Need to be combined them with Type 2a and/or Type 1
  - The Advantage of Type 2 electronics prototyping over Type 1 is speed and robustness
- Type 3: Integrated Modular Systems
  - Adding discrete components or building custom modules is often hard.
  - It simplifies and expedite electronics prototyping

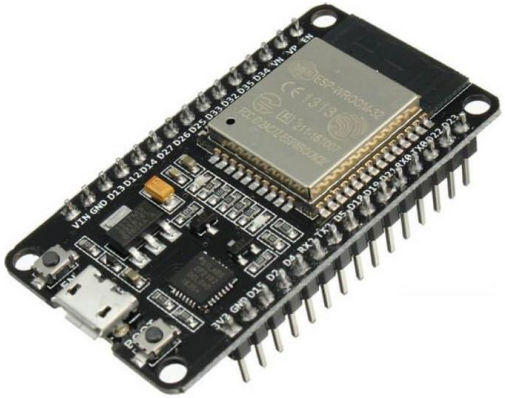


Toolkits

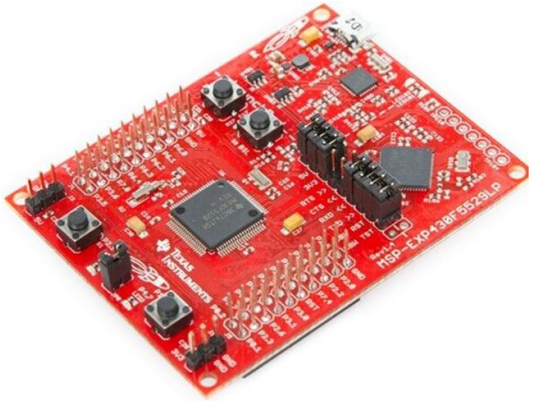
- Generic breakout boards
- Programmable low-cost WiFi modules
- Silicon vendor development boards
- FPGA development boards



Bosch BNO055
IMU sensor



ESP32



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ELECTRONIC PROTOTYPING PLATFORM TAXONOMY

- Nature and Application

	Specific toolkits			Generic Breakout boards	Low-cost WiFi modules	Silicon vendor MCU dev. boards		FPGA dev. boards
Type of electronics	Type 2a (35%)	Type 2b (10%)	Type 3 (65%)	Type 2b	Type 2a	Type 2a	Type 3	Type 2a
Electronic sub-domain	Wearables/textiles (15%)	Home automation (3%)	Interactive paper (3%)	n/a	n/a	n/a		n/a
	Robotic vehicles/drones (3%)	Musical instruments (2%)	Biomedical sensing (2%)					
	AI/ML (2%)	n/a (70%)						
Promoted with user groups (multi-value)	K-12 Education (50%)	Makers (77%)	Electronic engineers (35%)	Makers	Makers	Makers		Makers
				Electronic engineers	Electronic engineers	Electronic engineers		Electronic engineers

- Assembly of Prototypes

	Specific toolkits			Generic Breakout boards	Low-cost WiFi modules	Silicon vendor MCU dev. boards	FPGA dev. boards
Type of connection	Individual conductors (45%)	Multi-wire cables (27%)	Direct module-to-module (38%)	Individual conductors	Individual conductors	Individual conductors	Individual conductors
	Wireless (5%)						
Connection mechanism (multi value)	Friction fit (67%)	Magnetic (8%)	Locking (7%)	Friction fit	Friction fit	Friction fit	Friction fit
	Crocodile clips (8%)	Adhesive(3%)	Thread (3%)				
	Screws (2%)	Wireless (5%)					
Connection topology	Star (45%)	Hybrid (25%)	Bus (30%)	Star	Star	Star	Star

ELECTRONIC PROTOTYPING PLATFORM TAXONOMY (1)

- Deploying and Configuring

	Specific toolkits			Generic Breakout boards	Low-cost WiFi modules	Silicon vendor MCU dev. boards	FPGA dev. boards
Programming style	Physical configuration (20%)	Software configuration (75%)	n/a (10%)	n/a	Software configuration	Software configuration	Software configuration
Dependencies for programming (multi-value)	Fully self-contained (23%)	Connected wirelessly (12%)	Tethered to computer (73%)	n/a	Tethered to computer	Tethered to computer	Tethered to computer
	n/a (8%)						
Dependencies during deployment	Fully self-contained (80%)	Connected wirelessly(3%)	Tethered to computer(8%)	n/a	Fully self-contained	Fully self-contained	Fully self-contained
	n/a (8%)						

- Availability and Adoption

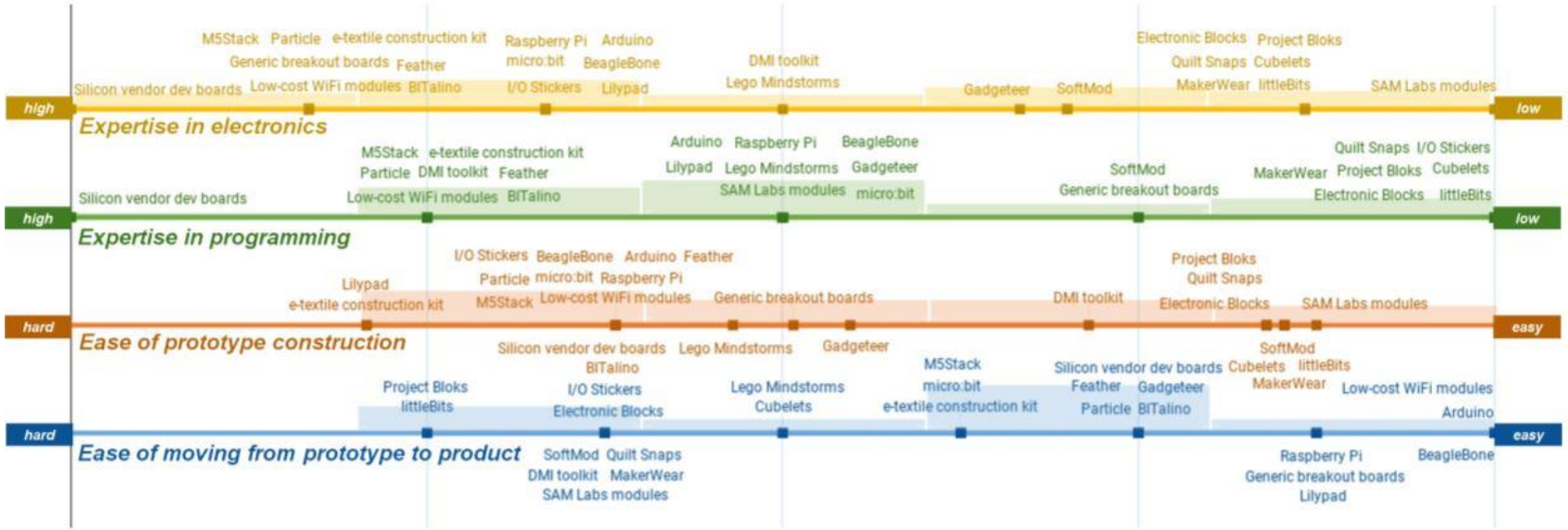
	Specific toolkits			Generic Breakout boards	Low-cost WiFi modules	Silicon vendor MCU dev. boards	FPGA dev. boards
Existing use	In commercial products (7%)	Multiple copies (7%)	Only used in one-offs (86%)	Multiple copies	In commercial products	Only used in one-offs	Only used in one-offs
Commercially available	Yes (67%)	No longer (2%)	Never (31%)	Yes	Yes	Yes	Yes
Third party use	Yes (86%)	No (17%)		Yes	Yes	Yes	Yes
Open source	Fully (45%)	Partial (42%)	Closed (13%)	Fully	Fully	Fully	Fully

ANALYZING THE CHARACTERISTICS

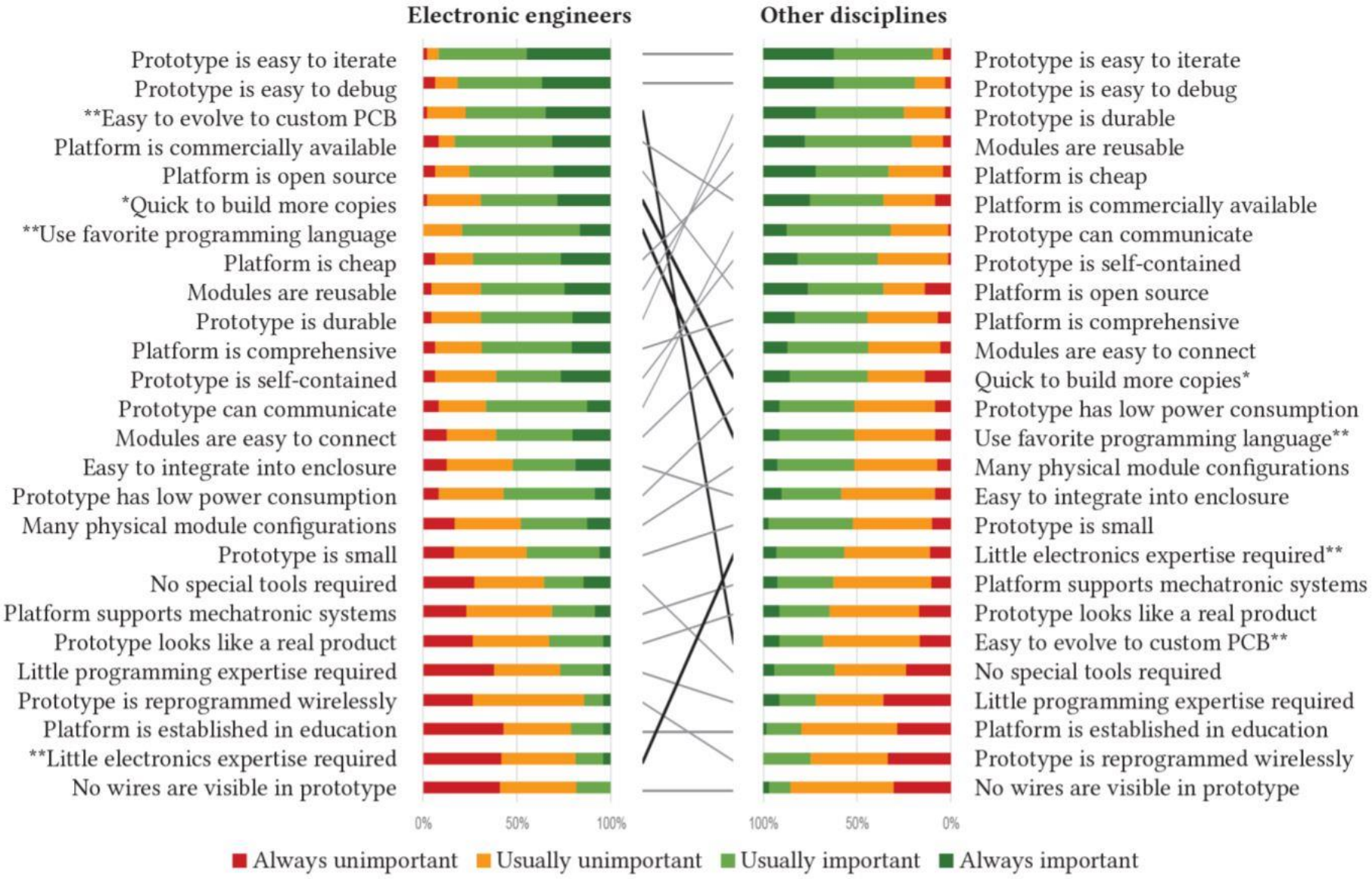
- The level of electronics expertise required.
  - Type of connection
  - Connection topology
- The level of programming expertise required.
  - Programming style
- The ease of construction of a prototype.
- Ease of moving from a prototype to a product.
  - Existing use
  - Dependency during deployment
  - Open source

ANALYZING THE CHARACTERISTICS (1)

- Ranking of prototyping platforms



SURVEY ON ELECTRONICS TOOLKITS



SURVEY ON ELECTRONICS TOOLKITS (1)

- Only 10% of our respondents often started the prototyping process with a Type 3 toolkit.
- 39% of respondents reported they often make copies using a custom PCB.
- 12% of respondents often make copies using the same prototyping platform as used for the one-off prototype.
- 53% of all respondents often start the process with Type 2a development boards, 44% often start with solderless breadboard.