

Title: Design and User Experience in Software for Medical and Psychological Research

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Keywords:

Vision/sensor; fusion, facial recognition; biometric data capture; emotion response detection; ultrasonic tracking for positioning and localization; mixed reality; physical computing.

CR Categories: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems –Artificial, augmented, and virtual realities; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism – Virtual reality

This paper draws from content in the upcoming text, “interAct - history of interaction design, experience and interactive art.”

1. Introduction:

Leveraging on several years of research and development in facial recognition, emotion detection, sensors, and vision systems, we produced a series of works that merge art, science, technology, and devices. Over the last eight years, our teams have designed software and mediated interactive experiences for research in psychology, and in medical research. This paper presents observations on the stakeholder interactions in planning of these software and hardware systems that may prove useful for medical and scientific researchers and developers of systems used in medicine.

First, we will present the work that led up to the creation of the software, Emota v4.0TM, and the considerations of how the design, specification, planning and implementation of this software occurred working with software developers and psychologists. Second, we will present the design of a new software used in medical research using vision and sensor systems to collect biometric data that is used in scientific and medical research.

2. Background

When considering the design of software for medical devices for both research & medical treatment, the stakeholders associated with development include individuals with diverse backgrounds & knowledge. Inevitably, knowledge & experience of these groups have only partial overlap. This paper is written to raise awareness of the interface design, user experience, & software design & development stakeholder's contribution & what area of expertise, they bring to a group of experts in medicine, psychology, & other participants in the projects.

My work as a software design & device development in the creation of gesture recognition, gait recognition, & facial recognition, emotion detection software, specifically Emota v4.0TM. Other earlier work includes positioning and localization using vision and ultrasonic sensing, vision and gyroscopic accelerometer sensor tracking of humans in real-time real-world environments for mixed and augmented reality, and vision detection of gesture recognition. Second, we will present the design of a new software used in medical research using vision & sensor systems to collect biometric data that is used in scientific & medical research. The images in Figure 1 depict a prototype electro-stimulation headset designed for a start-up company with researchers from MIT, Harvard & Boston Hospitals. This project requires, among other things, ergonomics, physiology & as well as software design for control & management of the electro-stimulation as well as data collection post priori to ascertain treatment effectiveness.

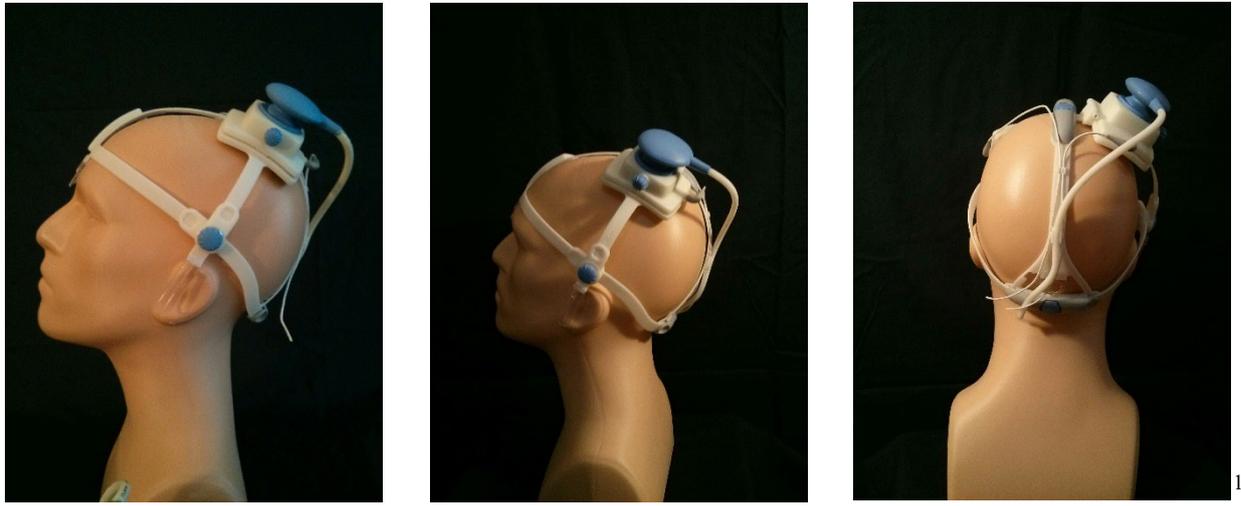


Figure 1: Prototype 3D printed electro-stimulation headset, Highland Instruments.

3. Analysis Methods in Interaction Strategy and User Interface

One of the considerations in design of these systems is how the specification, planning & implementation occurs with collaboration with software developers, medical research, practitioners & psychologists. There are a few basic assumptions that can be made in regard to all digital media artifacts, past, present, and future. There are stakeholders in the development of any artifacts. Any enterprise creating an app, device or service has a basic frame that is related to the primary goals of the enterprise - profit and return on the investment. While this area for framing can be overlooked in the analysis, doing so leaves a very large hole in the understanding of the artifact – since the artifact exists specifically in the culture and society.

For user experience designers to effectively contribute to functioning software or systems, they will employ a set of techniques that are analytical & process oriented. For analysis, the techniques of Constraints & Affordances Analysis, Frame Analysis, Formal Analysis, and Organizational Culture as tools are often employed. For stakeholders in medical practice, research, data analysis experts, & software engineers, they should understand terms & methods employed. However, the author contends that Design Process as an Analysis Tool may prove equally effective in framing phasic segment of specification, design, testing and implementation of interactive artifacts in psychological research, medical practice and research. Design process has been worked and experimented with to maximize user participation and engagement. In fact, user experience and experience design has resulted from efforts by luminaries in Human Centered Design such as Don Norman and Tim Brown of Stanford University’s D-School. Brown, et al, describes this as “Design Thinking.” These scholars, among many others, sought to find ways to increase product engagement through understanding just what the consumer is seeking to achieve and what the desires and goals are. In relation to the digital artifacts, one aspect of the work in the field of “Human-Computer Interaction” blended cognitive psychology with engineering resulting in effective interface and user interaction strategies.

To become experts in the usage required specific knowledge and mannerisms that were idiosyncratic to that specific device. Different manufacturers employed different methods, and while the end result may appear the same another artifact, a printed document used in a business or corporate environments the methods of creation depended on how that tool was developed, and the underlying computational structures of the assembly language and machine code. These depended on the architectures of the chipsets in the device.

Erving Goffman, credited with coining the term in his book *Frame Analysis*,² understood the idea of the “frame” to mean the culturally determined definitions that allow people to make sense of objects and events. For Frame Analysis to be an element of ethnographic research, data is collected in identifiable chunks of social behaviour, in order to understand the frames that participants use to make sense of the behaviour. Frame analysis can be adapted to specification and parameters for interactive tools for medical, by maintaining a focus on the research mission and determining specifications within this strict purview. Each tool used, while affording other potential uses, when used for medical or psychological data collection, is

¹ Figure 1: Images: courtesy the author, Electro-Stimulation device, Highland Instruments.

² Erving Goffman, Bennett Berger *Frame Analysis: An Essay on the Organization of Experience*, 1986, Northeastern University Press; ISBN-10 : 093035091X

most likely a solution to prior diagnostic or treatment practices. This provide the frame of reference for analysis that includes device behavior, as well as behaviors of practitioner that employs the device. This can be extended to physical cues and behavior of patients as well.

Design Process, for example, asks the user experience & interface design team to follow a set of stages that inform the design of the software coding as well as the interaction strategies of the users of such software & systems. One of these stages is also a frame analysis. Typically, the design process stages are:

- Frame the problem.
- Understand genre features.
- Refine familiar elements.
- Define usability, durability, aesthetics, both visual & tactile.
- Reframing to adjust behaviors of devices, tools, methods, to fit with established understanding.^{3,4}

Framing and Re-Framing

Reframing takes commonly understood objects and forms, using a new technology, allows the same conceptual framework, or “mental model” to be applied. This maintains a consistent and accessible mode of action for goals achievement. The use of the “tabs” in the browser, stacking multiple webpages carries the same cognitive model from the file folder. The cognitive model, or pattern is re-framed to allow the participant to undertake commonly understood actions and practices within the virtual environment of digital media and computing technology. Almost every software developed has been the solution to an earlier problem or to make some common tasks easier to undertake. In this each software is re-framing the actions, the process and possibly the results to enable the user to be more efficient and achieve more in the work at hand.

In a survey of how interface designers work, there will be some consistencies in the phases of their process. One is to start by considering the specifications for the work at hand. Following this will be an open-ended period of free-association, or possible ontological mapping of similar concepts, words, phrases, ideas, products, and other cultural artifacts. In the case of medical devices, there are often long used devices and practices that frame the work, the tasks and whatever analysis may result. The “framing” is much closer to machine design and engineering than social media to other interactive applications used today particularly those in social media or phone apps.

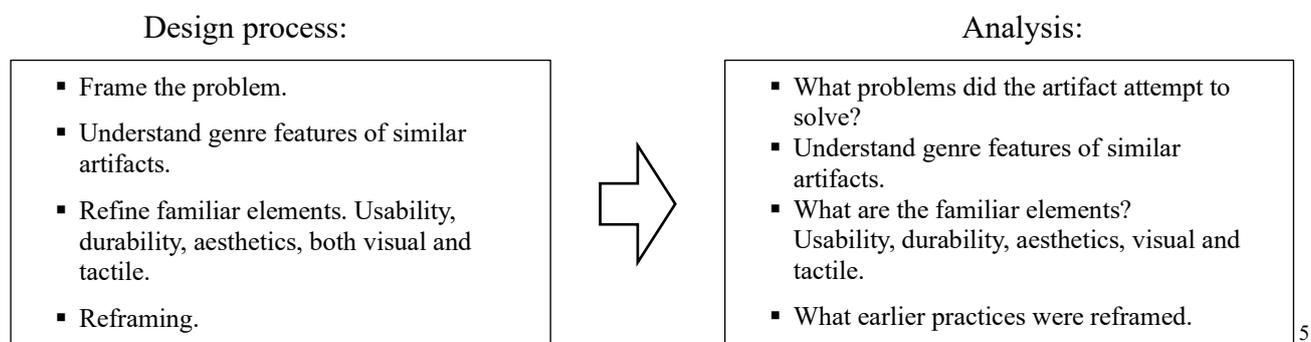


Table 1: Reframing design process as an analysis tool

Analysis of Constraints and Affordances

Using the example of the earliest artifacts created by early hominids such as flaked stones used for cutting, include first the recognition of the affordances of the object. Affordances are found by understanding the material of the object. A stone tool used for cracking nuts, or bones to get to the food inside indicates knowledge of the comparative hardness of the material of the stone versus that of the nut, or the bone. A flaked stone has a sharp edge, that sharp edge in use affords cutting and scraping of skin and flesh. These artifacts can be first assessed by the materials – hardness, durability, portability, sharpness of flake edges. After this assessment of the formal materials, there are the formal aspects of the tools use. To understand both the materials and use of a tool, or device, one needs to analyze the “constraints” of the materials,

³ Kelly, Nick; Gero, John (2021). "Design Thinking and Computational Thinking: a dual process model for addressing design problems". Design Science. 7: e8. doi:10.1017/dsj.2021.7. S2CID 233317330

⁴ Cross, Nigel. 2001, Design Cognition: Results from Protocol and other Empirical Studies of Design Activity, in C. Eastman, M. McCracken and W. Newstatter (eds.) Design Knowing and Learning: Cognition in Design Education, Elsevier, Oxford, pp. 79-103. ISBN 0 08 043868 7

⁵ Pensyl, W.R. “interAct” - history of interaction design, experience and interactive art, Design Process as an analysis method.

constraints of the methods of production, constraints of the possible uses. In an effective analysis of any artifacts, these constraints will inform the understanding of the object and assist in making conclusions of the cultural usage or its “form.”

Design of specific tools are constrained by material properties that enable what kinds of tool can be created. The afore-mentioned knapped stone tools in basalt are still known today as providing a keener edge than the finest steel. Production of a tool is also constrained by the materials and the methods needed for its production. This is a technological constraint. Other constraints such environmental constraints are those where the use and behaviors may be constrained by external factors. The use of some tools is impossible in dry conditions, and possible in rainy or wet conditions. There are constraints that are cultural. Formal behaviors within culturally codified activity are constrained by accepted behaviors.

There are volumes written on the subject of affordances and the study of how one understand items in an interface, in a tool, in environmental conditions, that allow the human to just how it is that the encountered items can be used. J. J. Gibson in *The Ecological Approach to Visual Perception* states, “The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill.”⁶ Norman and Kress stress that beyond material and technological constraints, both constraints and affordances have social and cultural potentialities. As Kress stated, there are ‘modal affordances’ that are often multi-layered and ‘affordances’ are not a matter of perception, but rather refers to the “materially, culturally, socially and historically developed ways in which meaning is made with particular semiotic resources.”⁷

Assuming that specific tools and methods in the medical field are exempted from notion of constraints and affordances, it so miss a critical aspect of how humans understand, perceive the world and operate within it. Humans operate by pattern recognition, however faulty that recognition is. An accepted pattern of behavior is a cultural constraint. In the case of navigation of large and dangerous machines, the use of a cultural constraint is imperative. Design researchers that explore medical environments, and interpersonal relationships between practitioners, treatment facilities and patients, such as Miso Kim, who takes a humanistic approach to design. Her holistic approach looks at more of the intangible elements in relationships, and this branch of design is referred to as service design. Kim’s practice in service design focused on enhancing the experience of patient dignity. It is implicit that both societal and cultural constraints are in the practitioner/patient relationship.⁸

Case: Highland Instruments Electro-Stimulation Device

In the case of the prototype electro-stimulation device, and other ground-breaking technologies and tools, framing for these devices may be difficult, as well as determining constraints other than material and technological. However, the affordances arise from physics and physiological and sometimes environmental factors. In the design of this device, researchers studied and tested many iterations of sensor, and electronic beam angles and placements. The device is similar to how an x-ray is used in diagnostics, or radiation bombardment is used in treatment. Thus, there are contextual and environmental constraints that must be considered. Coupling the electro-stimulation with sensor to detect immediate physiological responses or in subsequent treatment regimens enabled the practitioner to use the device as a tool with specific intent. In this case the device control system is where the application of user experience and interface design are employed. Custom software was developed to allow the clinician to use the tool in treatment, the communication infrastructure, could be managed in a wireless method, but in this case, a wired connection via RS-232, and USB proved more effective and reliable. When considering the interface, factors such as expert knowledge and adaptability to the control system are imperative. Some clinicians prove to be more adept at operating the device, under direct and even indirect supervision of a medical doctor. This is not dissimilar to technicians operating data collection devices such as X-Ray, ECG/EEG/EMG, MRI, CAT and PET scanning.

To be blunt, much technology uses medical diagnostic and treatment functions in a manner that is akin to machine control of earlier tools and technology. These devices are, as in the ultrasound device in Figures 2, 3 and 4,^{9, 10} are complex and cannot be simplified. This is the case with most of tool interaction and interfaces

⁶ J. J. Gibson, *The Ecological Approach to Visual Perception*

⁷ <https://multimodalityglossary.wordpress.com/affordance/>

⁸ Miso Kim, *An Inquiry into the Nature of Service: A Historical Overview*, *Design Issues* (2018) 34 (2): 31–47.

⁹ Figures 2, 3, Image credit, courtesy of the author.

¹⁰ Figure 4, <https://manufacturingsolutionsgroup.com/machining-processes-explained/>

that designers are tasked to create. They are in many ways like a complex interface for controlling a CNC milling machine for mechanical parts – very powerful machines for dedicated tasks.



Figure 2, 3, 4: Complex Machine Interfaces

It should be noted that software systems that control complex machinery and process generally have complexity of the interface corresponding to the power and range of possible actions and resulting work. In graphic arts, media CAD, and animation software, the learning curve is extremely steep, and the time to master such software is gauged in years, not months or weeks. Even with sophisticated user interfaces the processes being controlled are even more complex that is visible on the surface of the interface. In the paper *Big Data: A Classification Of Acquisition And Generation Methods*, Nanjappan, et al list, some examples of post-WIMP interaction styles: virtual, mixed and augmented reality, tangible interaction, ubiquitous and pervasive computing, context aware computing, handheld, or mobile interaction, perceptual and affective computing as well as lightweight, tacit or passive interaction.¹¹

Of these, tangible interaction, context aware computing and perceptual and affective

computing are directly related to device interfaces and interaction strategies used for biometric and medical data capture. Nanjappan, et al further state, “We believe that all of these new interaction styles draw strength by building on users’ pre-existing knowledge of the everyday, non-digital world to a much greater extent than before. They employ themes of reality such as users’ understanding of naïve physics, their own bodies, the surrounding environment, and other people. Nanjappan, et al give these interfaces a classification of Reality Based Interfaces. Interaction strategies that mimic reality alone is not enough. For Nanjappan, et al, Reality Based Interfaces principles should be traded against other considerations. These include:

- Expressive Power: i.e., perform a variety of tasks within the application domain
- Efficiency: perform a task rapidly
- Versatility: perform many tasks from different application domains
- Ergonomics: perform a task without physical injury or fatigue
- Accessibility: users with a variety of abilities can perform a task
- Practicality: practical to develop and produce

Anecdotally, the author contends that aside from widely used software applications and digital computing devices, these interface and interaction strategies indeed, also represent the “state of the art” in devices and systems in medical diagnosis and treatment. Additionally, Nanjappan, et al, characterize data collected using the various data type and sensor data collection as either structured or unstructured.

Structured data are usually defined with fixed attributes, type, and format—for example, records in a relational database are generated according to a predefined schema. Compared to unstructured or semi-structured data, processing of structured data is relatively simpler and more straightforward. This type of data can be generated by people, machines, and sensors.

- (1) Human-generated structured data: the data are created under explicit human involvement using some interaction mechanisms, e.g., data generated through human-machine interface devices like mouse input data and click-streams.

¹¹ Big Data: A Classification Of Acquisition And Generation Methods Vijayakumar Nanjappan, Hai-Ning Liang, Wei Wang, Ka L. Man

(2) Machine-generated structured data: the data are created automatically by a computing device without explicit human interaction, e.g., Web log data.

(3) Sensor-generated structured data: the data are generated by embedded fixed or moveable sensors, e.g., sensor data from smartphones and smart meters.¹²

Unstructured data are the opposite of structured data, without a predefined data model. Some common examples include text, images, audio, video, and streaming sensor data. Unstructured data are one primary source of big data and are much more challenging to process compared to structured data.

4. Facial recognition and data collection.

In the case of the software that the author has designed and implemented, we collect a combination of structured and non-structured data. Facial recognition and emotion detection uses what the author characterizes as “small data,” that results in a small range numerical classification – biological sex, some personal attributes, and classification of facial expression in the range of seven classical emotion states, as define by Paul Eckman.¹³ These results are used to invoke modifications media, or environmental spaces. In fact, in the iterations of the software, HiPOP™ and Emota™, there is no actual interface at all for participants. The software simply collects the data and invokes the response without the knowledge or actions of the audience or viewer. There is a more complex control system behind that which is seen by the audience. This can be complex but is used only to instantiate the software and system that then runs autonomously. These software systems are fully described further on.

Examples of how structured data may be arrived in facial recognition and emotion detection can be found in our software Emota v3.0™. This software techniques relies first on Viola and Jones’s Viola and Jones Open CV Haar-like features application^{14, 15, 16} and a “feret” database¹⁷ of facial image and support vector machine (LibSVM)¹⁸. pre-trained Haar Classifiers to locate facial features. Before feature extraction, lumen normalization was adopted to detect facial part of the image such that light conditions have less effect to the feature extraction process. Numeric features are extracted through convolutions with a set of pre-calculated Gabor filters called Gabor Bank. Gabor filters are implemented to derive orientations of features in the captured image using pattern analysis, directionality distribution of the features. Using Gabor filters increases accuracy of the anchor points derived in the elastic bunch graph matching.

Operations of elastic bunching graph include graph matching, graph pruning, and adding sub-graphs from either an image or an xml file. Elastic bunching graphs applies convolutions of certain areas of images using all filters in the Gabor Bank. This results in a list of anchor information for all anchor points, where each anchor information contains a list of all convolution results.¹⁹ This work was tested in the creation of a generative musical composition where the detection of emotion state via facial expressions alters tempo, timbre and pitch in a live unscripted musical stream.²⁰

The author’s teams went through two earlier iterations of emotion detection, with successful results. One main consideration has been a “universal” method that does not require specific training on a single face and will still provide accuracy that is usable in a practical application. The tradeoff is manly this, accuracy vs universality. In the case of the first facial recognition software the author developed, HiPOP,²¹ we successfully detect biological sex based on cues in facial features, the tradeoff was accuracy vs speed. The longer time to scan and compare features results in higher accuracy. In Emota v4.0™, we explored simultaneous use of a local algorithm and the Microsoft cloud based FaceAPI in a custom media control system running on a Raspberry Pi, 5 MCP23017 GPIO extender ICs, 5 sixteen bank relay clusters, to control patterns in an array of twenty-four traffic lights.²² Microsoft regrettably limited access to Azure AI Vision

¹² Ibid. Big Data: A Classification Of Acquisition And Generation Methods Vijayakumar Nanjappan, Hai-Ning Liang, Wei Wang, Ka L. Man

¹³ Ekman, P., (1999), "Basic Emotions", in Dalgleish, T; Power, M, Handbook of Cognition and Emotion, Sussex, UK: John Wiley & Sons,

¹⁴. Viola, P., & Jones, M. (2001). Robust real-time object detection. Paper presented at the Second International Workshop on Theories of Visual Modelling Learning, Computing, and Sampling

¹⁵ Bradski, G. and Kaehler, A., (2008). Learning OpenCV. OReilly.

¹⁶ Burges, C. J.C., (1998) A Tutorial on Support Vector Machines for Pattern Recognition. Data Mining and Knowledge Discovery 2, 121-167

¹⁷ <http://www.nist.gov/huma/nid/colorferet>

¹⁸ Ibid, Burges, C. J.C., (1998) A Tutorial on Support Vector Machines for Pattern Recognition. Data Mining and Knowledge Discovery 2, 121-167

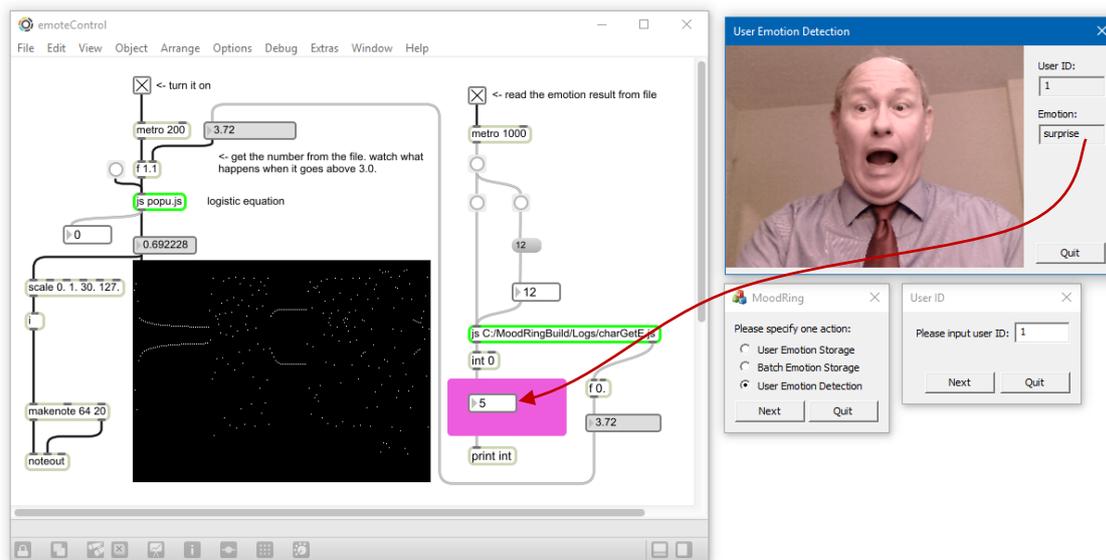
¹⁹ 2015 Pensyl W., Min, X., Song S., Facial Recognition and Emotion Detection in Environmental Installation and Social Media Applications Encyclopedia of Computer Graphics and Games https://doi.org/10.1007/978-3-319-08234-9_978-3-319-08234-9

²⁰ Cycling74 MAX/MSP

²¹ file:///D:/pensyl/p51Hi.html

²² file:///D:/pensyl/p51RGW.html

API to selected partners. Currently we use the local fall-back method. While, less sophisticated and less accurate this custom face/emotion detection that runs entirely on the Raspberry Pi.



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Figure 5: Screen shot of Emota v3.0TM applied to musical composition in Cycling74 MAX/MSP

One of the most advanced systems for emotion detection is develop by a team of psychologists and computer scientists at the Machine Perception Lab at University of California, San Diego. Emotient was bought out by Apple in late 2016 and much of the history and development can only be found in the “wayback machine” archives.²⁴ The core software use similar techniques in facial recognition and emotion detection the author’s Emota v3.0TM software solution but is far more adept at the recognition response. As stated in the description of “Auto FACS Coding,” the output of the face detector is fed directly to the facial expression analysis system (see Figure 1). First the face image is passed through a bank of Gabor filters at 8 orientations and 9 scales (2-32 pixels/cycle at 0.5 octave steps).



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Figure 6: Screenshot of the Emotient FACET SDK Demo Video

The filter bank representations are channeled to a statistical classifier to code the image in terms of a set of expression dimensions. We conducted a comparison of classifiers, including support vector machines (SVM’s), Adaboost (Freund & Shapire, 1996), and Linear Discriminant Analysis (Littlewort et al., in press, Bartlett et al., 2003). SVM’s were found to be very effective for classifying facial expressions. Recent research at our lab has demonstrated that both speed and accuracy are enhanced by performing feature selection on the Gabor filters prior to classification (e.g. Bartlett et al., 2003). However, the methods used affords detection of what Bartlett describes as “micro-emotions.” This is an extremely sophisticated

²³ <https://pensyl.com/p51Emot.html> | Cycling74 MAX/MSP

²⁴ <https://web.archive.org/web/20151116125123/http://www.emotient.com/> |

<https://web.archive.org/web/20151219062637/http://www.emotient.com/products>

²⁵ https://www.youtube.com/watch?v=9DmiqU8Cxs&ab_channel=Emotient

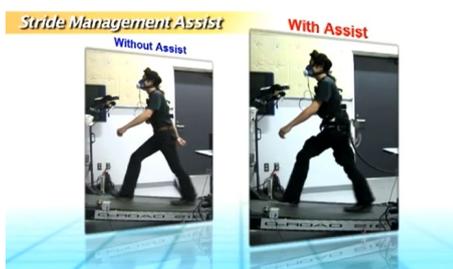
algorithmic approach that enables researchers to assess possible emotion states even in subjects that may attempt to hide their emotions. (sic)²⁶

At the time of writing, likely, the most sophisticated emotion detection today is found in Microsoft's Azure AI Vision API. This is a cloud-based software solution that allows participants to upload images and video stream and the results are delivered back to the participant software application. Microsoft's earlier iteration, Emotion API takes a facial expression in an image as an input and returns the confidence across a set of emotions for each face in the image, as well as bounding box for the face, using the Face API.²⁷ The confidence is given back in a numerical scale, that could be classified in one of Eckman's, classic emotion states.²⁸ Earlier iterations of the Face API have been scrubbed from Microsoft Azure site, but can be found on the waybackmachine.²⁹

The design of such software systems and the user interaction strategies may have serious implications for researchers. The goals of exactly what the expected outcomes in data collection require stringent specification. The are limitations to every sensing system that include frequency of data point collection. In terms of facial recognition, the speed of typical video capture speed of 30 or 60 frames per second is likely adequate for assessment of facial expression, body positioning. However, is researchers need to couple other data capture, such as EEG, or other sensing devices, some limitations of the computer system and operating system may cause issues in data capture and any subsequent analysis. If software based real-time categorization of information collect the timing and synchronization of the data points become critical. Given advances in artificial intelligence agents designed to process and provide analysis, these concerns will be important considerations. Timing and synchronization of various sensing devices will be presented in depth in a later case study presented in this paper.

In terms of the user interface, there is little concern as the data capture can be affected by user performance or expertise. In many cases, the user interface for such systems is a simple instantiation of the system. This is particularly the case with only one or two sensing devices. If multiple sensing devices are used, then some considerations of user interface structure, affordances and action flow need to be addressed in the user interaction specifications.

The ideal circumstance for such system may be as what Janet Murray refers to the computing functioning as a passive companion³⁰ that can collect data unobtrusively. We can see such systems being commercially employed by enterprises such the shopping experience recently rolled out at Amazon's Whole Foods when the costumer scans their palm on entry, and each item selected is automatically scanned and catalogued in the "electronic shopping cart" and payment is automatically processed without any over actions on exit. If one considers the use of RFID sensors embedded in consumers arms, use for bar tabs, and direct billing as has been around for over a decade in some European cities, the possibility of using real-time tracking and data capture is obvious.³¹ Another interesting example of such systems was deployed by Sergio Albeic, sponsored by Lexus where automobile sensor data was captured in real-time to paint a generative portrait of the driver on the tablet screen.³² The characteristics of the image reflected the manner of the drivers' actions. Aggressive driving results in a cruder image, while gentler and steady driving results in softer imagery.



Extrapolating the possible applications of data collection, the methods of data collection, and analysis easily leads to solutions for behavior assessment – and on a darker side behavior modification. Medical applications for muscle, brain, and nervous system stimulation are becoming common. Much of this was foreshadowed by artists such as Stelarc experimenting with embedding electrodes in the body³³ to allow remote "tele-operation" by persons in far-away locations to force involuntary muscle movements in artistic/theatrical performance art.

*Fig7*****

²⁶ Bartlett, M.S., Littlewort G., Movellan, J. Frank. M.S. | <https://inc.ucsd.edu/mplab/79/>

²⁷ <https://web.archive.org/web/20190110164611/https://docs.microsoft.com/en-us/azure/cognitive-services/face/overview>

²⁸ Ekman, P., (1999), "Basic Emotions", in Dagleish, T; Power, M, Handbook of Cognition and Emotion, Sussex, UK: John Wiley & Sons,

²⁹ Ibid. <https://web.archive.org/web/20190110164611/https://docs.microsoft.com/en-us/azure/cognitive-services/face/overview>

³⁰ Janet Murray, Inventing the Medium - Principles of Interaction Design as a Cultural Practice Chapter 12, The MIT Press

³¹ <https://pourmybeer.com/beverage-wall/>

³² <https://www.sergioalbeic.com/wall/the-generative-identity-of-walter-vanhaerents.html>

³³ http://stelarc.org/_php#page/7 | http://stelarc.org/_php#page/8

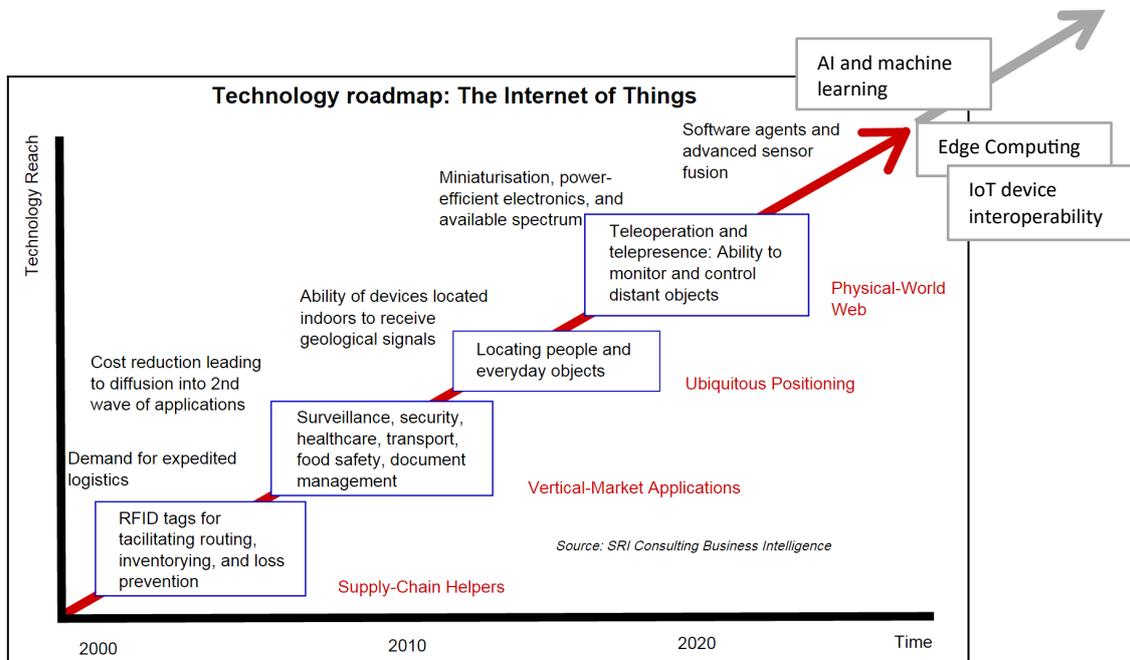


Figure 8: The state of the Internet of Things circa 2025

Given the current state of the “internet of things,” we are well past software agents and advance sensor fusion as indicated in Figure 8.³⁴ The author AI search agent, gives an indication of the next few years:

- Edge computing where data collection, processing and analysis occurs closer to the source, reducing latency and improving real-time decision-making.
- AI and machine learning enable software agents to predict maintenance, anomaly detection, and improved decision-making. The implication is that this can happen without human intervention or even cooperation.
- The Internet of Things Consortium and the Open Group are developing standards and guidelines for IoT device interoperability – similar to what Berners-Lee did for sharing of data content via a standardized mark up, hypertext transfer protocol and uniform resource location.

In terms of ease of use, creation of standardized protocols, and interface-less software agents is perhaps the best for the average consumer, where an intelligent system collects data and provides a meaningful passive action. However, as the tools used become more complex and powerful, complexity of interface interaction increases correspondingly to the power of the machine, or system. The expectation of expert knowledge of the operator to successfully managed processes for the intended result is still here, and in some cases, increases the learning curve and specialization of that expert knowledge. For advanced software in media – editing 3D modeling, animation, image editing, and in CAD/CAM, or mathematics and science the complexity of interface has not become simpler over time. In most software applications, the complexity of continues to increase.

This leaves researchers in many fields in situations where vast knowledge software engineering advanced coding and hardware specifications is required - or - to work in teams with experts in other domains. The crux of this paper is aimed at cases where there are several stakeholders in the development of software tools that use a variety of sensing and data collection for research.

Complex mathematical formulas inevitably require breaking the formula in the sections that can be processed in the native code of the API. Each language has specific syntax and structure. A formula in C+ has to be rewritten in C# or Python. These idiosyncratic methods become more complex with the number of parameters needed to gather useful information for research purposes. Working in team-based environments, communication on what the expected outcomes of the coding and processing of raw data is sometimes confusing. A software engineer may prefer to write in Python. However, the development of a system requires the use of devices where the Application Programming interface (API) is written on C#. it is unlikely that the device manufacturer will rewrite the API to suit the application a researcher is developing.

³⁴ https://en.wikipedia.org/wiki/File:Internet_of_Things.svg | Public Domain, Title 17, Chapter 1, Section 105 of the US Code

Even a simple set of mathematical functions, such as for calculating angles in a trapezoid, seen in Figure 9³⁵ that can be easily processed by hand, becomes 80 lines of code in C# as seen in Figure no 10.³⁶ It is not a straightforward simple translation, due to the syntax and idiosyncrasies of the software language. The formula used in our Emota v3.0 is seen in Figure 11.³⁷

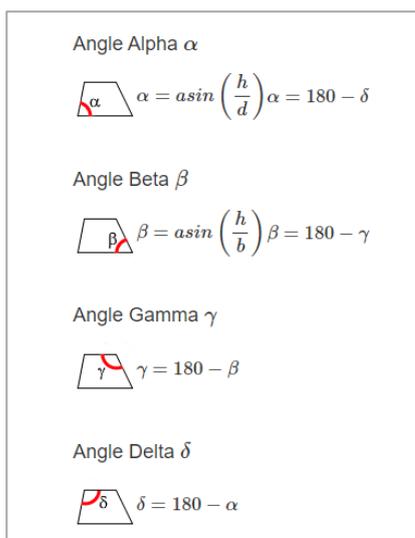


Figure 9: Function for calculating the trapezoid angles.

Anecdotaly, in a project where the author developed a large number of interactive tutorials for a population college level textbook in Chemistry, illustrates perhaps the worst-case scenario. The consulting professor working on the book, stated something to this effect: “here is the formula for the “Equilibrium of NO_2 and N_2O_4 ” the module required to graph the resulting change concentration of these chemical agents over time.³⁸

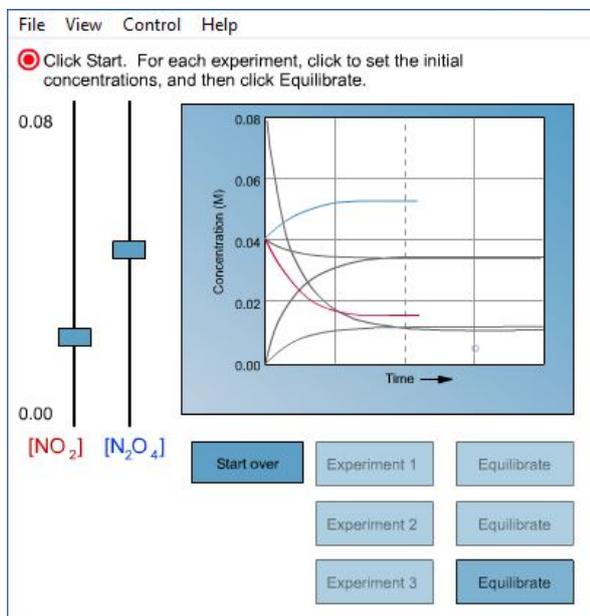


Figure 12: Equilibrium of NO_2 and N_2O_4 , courtesy the author.

```

1  /// <trapezoid>
2  /// The following class represents simple functionality of the
3  /// trapezoid.
4  /// </summary>
5  using System;
6
7  namespace MathClassCS
8  {
9      class MathTrapezoidSample
10     {
11     private double m_longBase;
12     private double m_shortBase;
13     private double m_leftLeg;
14     private double m_rightLeg;
15
16     public MathTrapezoidSample(double longbase, double
17     shortbase, double leftLeg, double rightLeg)
18     {
19         m_longBase = Math.Abs(longbase);
20         m_shortBase = Math.Abs(shortbase);
21         m_leftLeg = Math.Abs(leftLeg);
22         m_rightLeg = Math.Abs(rightLeg);
23     }
24
25     private double GetRightSmallBase()
26     {
27         return (Math.Pow(m_rightLeg,2.0) - Math.Pow(
28         m_leftLeg,2.0) + Math.Pow(m_longBase,2.0) +
29         Math.Pow(m_shortBase,2.0) - 2* m_shortBase *
30         m_longBase) / (2*(m_longBase - m_shortBase));
31     }
32
33     public double GetHeight()
34     {
35         double x = GetRightSmallBase();
36         return Math.Sqrt(Math.Pow(m_rightLeg,2.0) -
37         Math.Pow(x,2.0));
38     }
39
40     public double GetSquare()
41     {
42         return GetHeight() * m_longBase / 2.0;
43     }
44
45     public double GetLeftBaseRadianAngle()
46     {
47         double sinX = GetHeight()/m_leftLeg;
48         return Math.Round(Math.Asin(sinX),2);
49     }
50
51     public double GetRightBaseRadianAngle()
52     {
53         double x = GetRightSmallBase();
54         double cosX = (Math.Pow(m_rightLeg,2.0) + Math.Pow(
55         x,2.0) - Math.Pow(
56         GetHeight(),2.0))/(2*x*m_rightLeg);
57         return Math.Round(Math.Acos(cosX),2);
58     }
59
60     public double GetLeftBaseDegreeAngle()
61     {
62         double x = GetLeftBaseRadianAngle() * 180/ Math.PI;
63         return Math.Round(x,2);
64     }
65
66     public double GetRightBaseDegreeAngle()
67     {
68         double x = GetRightBaseRadianAngle() * 180/
69         Math.PI;
70         return Math.Round(x,2);
71     }
72
73     static void Main(string[] args)
74     {
75         MathTrapezoidSample trpz = new MathTrapezoidSample(
76         20.0, 10.0, 8.0, 6.0);
77         Console.WriteLine("The trapezoid's bases are 20.0
78         and 10.0, the trapezoid's legs are 8.0 and 6.0");
79         double h = trpz.GetHeight();
80         Console.WriteLine("Trapezoid height is: " +
81         h.ToString());
82         double dxR = trpz.GetLeftBaseRadianAngle();
83         Console.WriteLine("Trapezoid left base angle is: "
84         + dxR.ToString() + " Radians");
85         double dyR = trpz.GetRightBaseRadianAngle();
86         Console.WriteLine("Trapezoid right base angle is: "
87         + dyR.ToString() + " Radians");
88         double dxD = trpz.GetLeftBaseDegreeAngle();
89         Console.WriteLine("Trapezoid left base angle is: "
90         + dxD.ToString() + " Degrees");
91         double dyD = trpz.GetRightBaseDegreeAngle();
92         Console.WriteLine("Trapezoid left base angle is: "
93         + dyD.ToString() + " Degrees");
94     }
95 }

```

Figure 10: Coded C++ math functions to calculate the inner angles of a trapezoid.

³⁵ <https://www.redcrab-software.com/en/Calculator/Trapezoid-Angle>

³⁶ <https://learn.microsoft.com/en-us/dotnet/api/system.math?view=net-8.0#code-try-2>

³⁷ 2015 Pensyl W., Min, X., Song S., Facial Recognition and Emotion Detection in Environmental Installation and Social Media Applications Encyclopedia of Computer Graphics and Games <https://doi.org/10.1007/978-3-319-08234-9> = 978-3-319-08234-9

³⁸ Pensyl. W.R. Interactive Tutorial for Bruice, McMurry and Faye Chemistry e2. Prentice Hall/Pearson 1998

However, in the now deprecated Flash development software, a math function library was non-existent. One had to write some arithmetic, feed the result into a variable, and then pass the variable to the next piece of arithmetic. Explaining this to the consulting professor demonstrates communication issues in team-based work. This has decreased since digital literacy and advances in programming environments that include libraries such as a math library. A library can be called at the head of the code to import the appropriate function. Comparing solving a math equation on paper – the process must be adjusted to fit within the syntax of the programming language. **Depending on the devices being used the API may be written in C#, C++ and an efficient algorithm may become cumbersome requiring hours of debugging and testing.**

An example from the afore-mentioned software, Emota v3.0™, required the filtering of inconsistencies in a captured image that compensated for shadows. If one is image processing in real-time, then considerations of optimization of the process and code is warranted. (There is a cost to accuracy in “compute cycles.” Generally speaking, high accuracy in facial detection will result in slower processing times.) As we stated in our paper, “a vague shadow will not heavily affect Haar classifier performance, and hard shadow edges can be weakened. Thus, instead of complex shadow removal algorithm, we adopt following operations to concentrate effective image information so that Haar classifiers can find target more easily.”³⁹ The formula used is seen in Figure 12. Writing this in the most recent version of Python where a math function library can be called, results in this code seen in Figure 13.

$$f(x) = \begin{cases} \alpha K \log(x) + (1 - \alpha)x & , \text{if } x < 127 \\ \alpha [255 - K \log(x)] + (1 - \alpha)x & , \text{if } x \geq 127 \end{cases}$$

Figure 12: Simple shadow removal formula for Haar Classification

```

shadowAdjust.cs
1 using System;
2 using System.Math;
3
4 public class Program
5 {
6     private static readonly double ALPHA = 0.64;
7     private static readonly double K = 256;
8     private static double varAdjust = 1;
9
10    public static double Function(double x)
11    {
12        if (x >= 127)
13        {
14            return ALPHA * K * Math.Log10(x) + (1 - ALPHA) * x;
15        }
16        else
17        {
18            return ALPHA * (255 - K * Math.Log10(x)) + (1 - ALPHA) * x;
19        }
20    }
21
22    public static void Main()
23    {
24        double x = 254;
25        double functionX = Function(x);
26        varAdjust = (double)x + ", f(x) = " + functionX;
27        Console.WriteLine($"Input: x: {x}, f(x) = {functionX}");
28    }
29 }

```

```

shadowAdjust.py
1 from math import log10
2
3 ALPHA = 0.64
4 K = 256
5 varAdjust = 1
6
7 def function(x: float):
8     if x >= 127:
9         return ALPHA * K * log10(x) + (1 - ALPHA) * x
10    else:
11        return ALPHA * (255 - K * log10(x)) + (1 - ALPHA) * x
12
13 x = 254
14 function_x = function(x)
15 varAdjust = (f"Input: x: {x}, f(x) = {function_x}")

```

Figure 13, 14: The shadow removal formula in C# and in Python Script using math library.

What these instances reveal is the importance of clearly defined specifications in what is input what are the expected outcomes. These are paramount concerns in scientific or medical research and other considerations are subservient. Software engineers, and user interface designers speak in different languages, almost. Much software engineering operates in Murray refers to as the “black box”⁴⁰ for others in the team. Yet, with clear specifications for how the data is captured and the expected results are clearly defined, the stakeholders can work effectively together. For a single user, or researcher that writes their own code, the interface can be crude and as arcane as possible. Since the person that is operating the software knows exactly what each element does, the need for an “interface” is limited or even non-existent. The image in Figure 13 is developed in Cycling 74’s MAX MSP™ for detection and tracking of position of persons or objects using a webcam for control a stepper motor or other devices in an interactive media installation.

MAX MSP™ is a software development platform used primarily by music composers and artists. It has very idiosyncratic programming method. In the workspace, the operator sets a series of various modules where

³⁹ Ibid Pensyl W., Facial Recognition and Emotion Detection in Environmental Installation and Social Media Applications

⁴⁰ Ibid, Janet Murray, Inventing the Medium - Principles of Interaction Design as a Cultural Practice Chapter 12, The MIT Press

each represent discrete piece of code, and feeds information between these. The operator does not need an interface that make it easy to use as the requirement of functionality overrides the need for an interface. Figure 14 shows a “presentation” mode of the above-mentioned tracking software,⁴¹ where the functions are “cleaned up” and structured into a rudimentary interface. Even this kind of interface is complex. Working with student usability testing this tracking software still required training. In other words, that interface need more affordance!

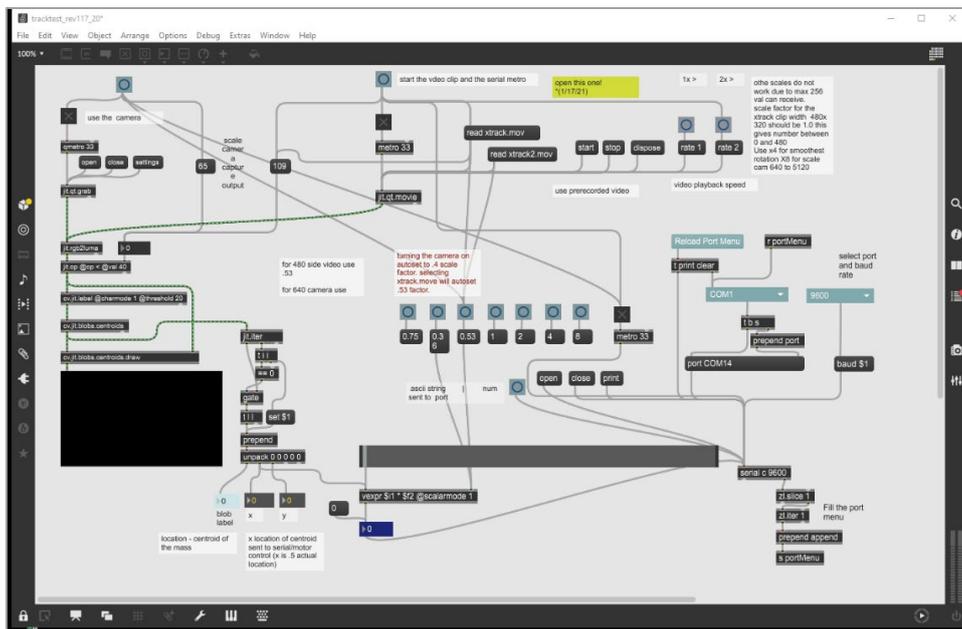


Figure 13: Motion tracker software workspace in MAX MSP™, courtesy of the author.

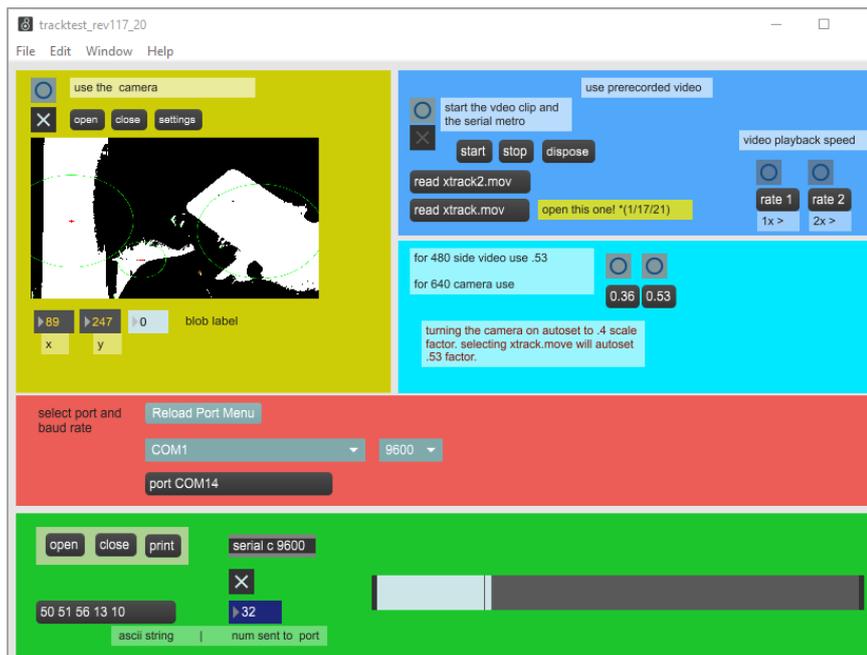


Figure 14: Motion Tracker “presentation mode” MAX MSP™ executable interface. Courtesy of the author.

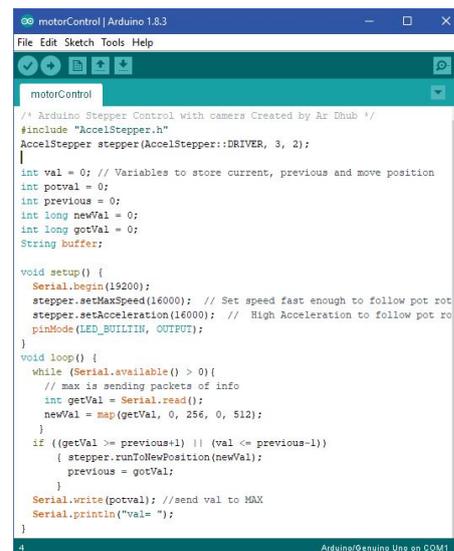


Figure 15: Arduino ISP code uses the Javascript syntax

Even with such development platforms, it is still needed to write custom code in another high level programming language such as Javascript or C++. In such applications, the need to design companion systems to control devices often requires writing custom software using microcontrollers as used in the Motion Tracker mentioned above. This particular system is a designed as an autonomous “surveillance” app that detects and track humans and follows their movements. The motor control is handled with a Arduino that collects the tracking data via serial port and in a compiled code uploaded to the firmware of the micro-controller, seen in Figure 15.

⁴¹ Pensyl, W.R. Motion tracker executable compiled from Max MSP™, Cycling 74

The earlier mentioned emotion-detection controlled music app in MAX MSP™, emoteControl™, required custom Javascript code⁴² to get the detected emotion facial expression from the Emota v3.0™ executable. (Figure 5.) Serial communication is used in real-time to modify the music stream in the Javascript seen in Figure 16.

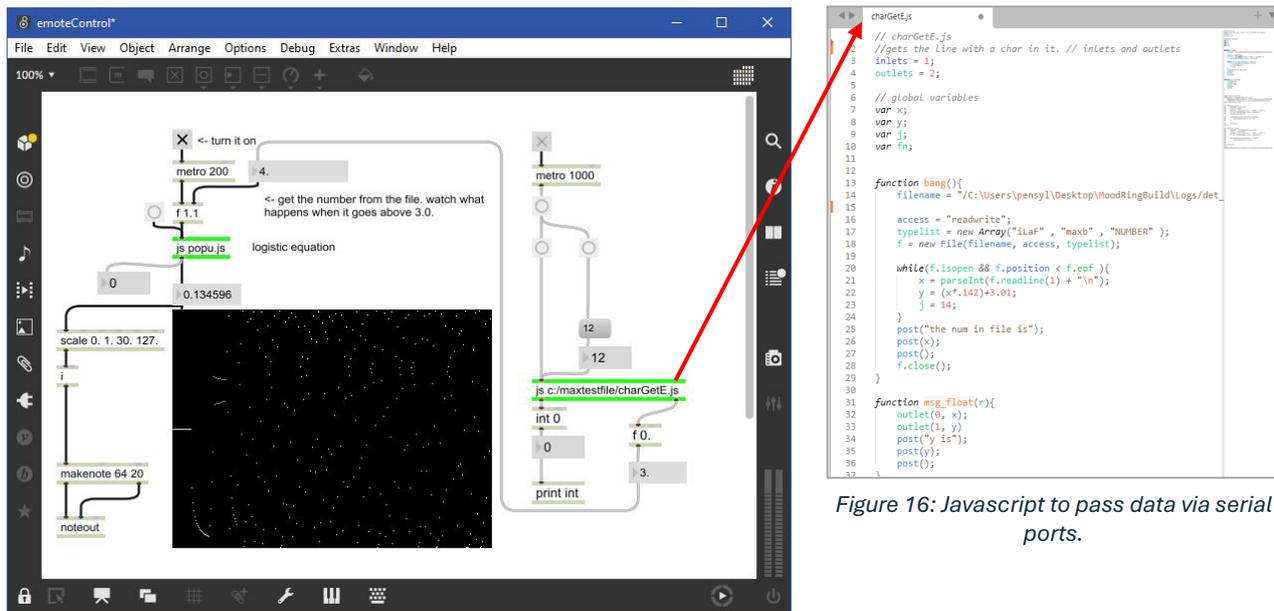


Figure 16: Javascript to pass data via serial ports.

Figure 16: Custom Javascript code affords communication between emoteControl Music app and Emota v3.0.

In the afore-mentioned music application, emoteControl™ was developed in MAX MSP™, while facial recognition and emotion detection was carried out in Emota v.3.0™. These two software applications run simultaneously.

In any development someone in the team must handle software engineering. In some instances, there is a need for an electrical and electronics engineer to build custom or modify sensors and devices. These tasks can be completed by the primary researcher or principal investigator. But it will be more effective for the research team to include members that can handle these various tasks – affording the PI to focus on the research. Once team-based work commences the need for proper communication becomes more important. The engineers, especially software engineers, are essentially speaking a foreign language with a completely different linguistic syntax and structure. The computer devices work in machine language that is several steps away from natural language.

5. Specifications of hardware/software for team-based development of research tools.

In this section we will address some of the most critical aspects of hardware and software development. This includes technological constraints – limitations and affordance of the technology. There are many and the complexity increases with each additional data collection device and data points added. Beyond this are cultural constraints in how a participant interacts with the system. The user interface and interaction strategies. Both inform and constrain how the system is used. There may be significant impacts on data collection due to how the interface and “flow” are designed.

Depending on the type of data needed, and how that is to be analyzed, the considerations of the level of the computer used needs to be considered. As a basic rule of thumb, the higher performance of the computer should be in most cases, the first consideration. However, the author has encountered instances where very high-performance workstations cannot be configured to capture data effectively. As a general rule, the higher the performance of the graphics display card is valued. The arithmetic processor and high amounts of RAM in these cards can be leveraged for many applications. But once, again, depending on kinds of data needed, we have also seen that some of the highest performance NVidia RTX cards with chipsets and instruction sets that work very well for high-end graphics display, gaming and rendering of three-dimensional graphics – conflict with instruction sets in the highest performing visual sensing and data capture devices. The author encountered such circumstances with military-grade vision systems used in weapons systems and self-driving automobiles. Another consideration in the selection of graphics display cards are the specifications

⁴² Custom Javascript code in MAX MSP™

for throughput on PCI bus. Also, software interaction in APIs and SDKs for the graphics cards may impact on sampling frequency in data collection. These considerations require testing of the various systems to ensure that the data capture is effectively undertaken to ensure the research is enabled.

In testing computing systems, the CPU communications components, such as Bluetooth, WIFI, and other devices, that the research team may employ require testing to ensure that the system is robust and support the number of sensors needed. For example, some laptop systems used in high intensity graphics offer two USB buses internally. This allows for some input devices and external display devices to run on different buses. Quite often, the two or three built USB ports are not enough to connect the number of input devices needed for research data capture. Selecting a system with two internal USB buses enables the use of multi-port USB docks.

Anecdotally, the author has encountered instances where preference for the use of Wi-Fi communication between sensor devices for mobility of the subject. Yet there are disadvantages to Wi-Fi communication. Virtually of the wireless sensor devices commercially available operate in the same 2.4 GHz frequency band. Communication on this spectrum in most environments includes other people's computers, wireless communications in smart phones, your neighbors or family members using the television remote, garage door remote or other devices. Since all of these are on the same 2.4 GHz frequency spectrum even with the most sophisticated methods of communication, there will be:

- Signal interference and disruption by other devices or physical barriers.
- Signal range limitations.
- Security risks in hacking and unauthorized access.⁴³

For some research, especially funded research in the US, by National Institutes of Health, and some National Science Foundation, security of subject and research data is controlled at an extreme level. Many have strict rules of blocking internet access, and physical security of the environment as well. Use of Wi-Fi communication with sensors is controlled as well with stringent rules for encryption and anonymity of data.

This may seem like a trivial point, given the speed and processing power of Intel's 8th Generation processors today with 4, 8, and 14 cores in a single CPU. A core in the CPU is essentially multiple CPUs in one – allowing simultaneous multithreading, a form of parallel processing. However, even with extremely high performance multi-threaded processing, one can encounter bottlenecks in internal communication with various components. System level processing interrupts increase with number devices collecting data. Developers are encouraged to review documentation on interrupt staging and processing.⁴⁴ There are two primary types of CPU interrupts, evoke by external devices, such as sensors Hardware interrupts include keyboard, mouse or touch surface, or reading and writing to the hard disks. Software interrupts are triggered by the CPU itself or the running application where a process invoked by software requests attention from the CPU. Any of these may require CPU compute cycles that cause disruption in the data capture. The author has experienced instances of UI interactions that overlap and cause intermittent system crashes. Solutions to these are writing process delays that allow one process, or device instantiation to complete before allowing another process to be invoked in the UI.

These kinds of bugs are difficult to track as the complexity of the system increases, and that complexity is inherent in increasing the number of devices used to capture data in a running process session.

For non-experts in digital technology acquiring a basic understanding of how the computing machine functions will be useful in specifying what the system is to return in the data collection. As mentioned, the software engineer is tasked with implementing the coding in such a manner as to effectively marshal the computing system and communicating with external sensor to provide the data needed for the research. Following this the software engineer may be involved in writing custom scripts for analysis of the data.

In terms of understanding what the software engineer is tasked with we can look at the simple code in figure 15. The code there is structured to use a single microcontroller, such as an ARM, (Advanced RISC Machines)⁴⁵ and the Arduino integrated development environment (IDE.) There are a number for basic components that can be used on this single board microcontroller that make a very effective learning tool for hobbyists, and non-engineers. The operation demonstrates the basic manner in which commands are

⁴³ <https://www.cisco.com/c/en/us/products/wireless/what-is-wifi.html>

⁴⁴ <https://www.tutorialspoint.com/what-are-the-interrupt-stages-and-processing>

⁴⁵ https://en.wikipedia.org/wiki/ARM_architecture_family

executed in computing devices. This simple example shows the structure of commands that operate in a loop. The loop, called a “void loop” in the Arduino IDE, executes, and returns to execute again, continually. Within the loop there are some conditional statements that execute an action when the condition is met. The first condition is to check if the serial port is available and open. If so, then the value in the serial port buffer is read and stored in location for later use. Following the met condition and storage there is another condition that determines if the stored value from the serial port meets a threshold. If then, else statements are common basic programming methods to invoke commands and controls to internal components and external devices. In the case of this example, we read the contents of the serial port, check it. If the value is equal to or greater than the last read value, we write this new value back to the serial port – the companion program then rotates a motor by the degrees and in the speed specified.

In all CPUs there is a clock that pulses at a specified frequency. Each pulse of the clock tells the CPU to execute one of the commands, such as to read from a memory location. What is read could be an instruction, or stored data. The sequence of the instruction set in the CPU loops, similar to what was described in the simple Arduino example above. Each one of these loops is generally called a “compute cycle.” The more advanced the software controls, and the components, external input and output devices and have “costs” in compute cycles. Overly bloated software, and system add-on have costs in compute cycles. Efficient software will eliminate unnecessary code and instructions, and also order those instructions to avoid bottlenecks in communication and collecting of data, or processing of information.

In specifying a computer system using commercially available operating systems, like Windows, one has to take care to delete, and turn off the bloatware that the manufacturer installs. There are often processes that run in background, unknown to the user that exhaust the CPU with unneeded execution. The software engineer’s coding and then runs effectively – provided that care is taken to structure the operation to achieve the intended goal. An excellent reference for understand how computer systems work is the book, “But How Do It Know?”⁴⁶ In this text, Scott describes a “theoretical” CPU that illustrates in layman’s terms the concepts of computer architecture and the construction of a CPU. The CPU is an 8-bit design, and the book provides a step-by-step guide on how to build it from the ground up. There are also very good videos published on youtube that describe the CPU using the Scott CPU as a base.⁴⁷ There are many instances online of individuals using this blueprint to create functioning 8-bit computer. Using an Arduino is what the author recommends for learning, since all the components exist and can be programmed with minimal computer science knowledge. Arduino has an avid following of enthusiasts that build upon the platform and share their contributions.

One important aspect of data collection – as well as for many other applications – is the frequency response rate of the data collection. Devices are:

- CPU
- USB Bus transmission speed
- Hard-wired Sensor
- Wireless Sensors (Bluetooth or Wi-Fi)
- Vision systems

The CPU, “system” clock managed by the operating system. Code in a high-level languages like C# or C++ can collect an event in “system time” as a data point. Sensors or other external input devices used to collect data may or may not have a clock. Some devices simply stream data as fast as their internal components run. Accessing the internal timing is not available in the device API.

Other devices will native functional frequency (Hz) +/- a small variation and ideally, the device API provides a “device clock” that can be collected as a data point. In some instances, the device clock is fixed, and in others the software engineer can send a command to the device to set its internal timing frequency to optimally transmit data with a minimum of data loss (drop-out.)

Still other devices will have a strict internal clock that is a fixed frequency. Vision systems are often designed using robust timing mechanisms (device clocks) that run at the standard rate of 29.97 Hz (29.97 frames per second.) This standard is referred to as “SMPTE” time code and is an accepted timing built into

⁴⁶ John C Scott But How Do It Know? - The Basic Principles of Computers for Everyone 0615303765 <http://amzn.to/1mOYJvA>

⁴⁷ https://www.youtube.com/watch?v=cNN_tTXABUA

almost all video and film cameras and recorders allowing for accurate editing, synchronization, and identification of media.

Here is where things get interesting for the research team: each device used, including the CPU, operates on different time scales. One of the important considerations for data collection for medical research is synchronization of data points that represent events in physiology processes. Data collection for medical research needs to be at a frequency that is commensurate with response frequencies of the brain and the nervous system. But each of the devices used to collect the data is working in different time scales.

Furthermore, when the software invokes a command to instantiate a device or to then collect a data point – this command is invoked in system time. However, there is inevitably a delay in the time it takes for the CPU to send the command, and the data is returned to the collection method. In cases where the data point represents critical physiological events, this discrepancy can render data collection problematic and even unusable for analysis. Compounding this may be background operating system process and overhead.

Even with extremely fast multi-threaded and “parallel” processing, events in parallel streams and threads do not happen simultaneously – due to the very nature of how the CPU clock pulses and commands are issued.

Working with WIFI or Bluetooth devices for data collection, one has to consider sampling frequencies of devices used for data collection, the system clocks Can it be reliably used? Data collection in wireless devices is probabilistic data in transmission and in capture. A data point even with a device clock may not happen at a discreet time. The frequency of data collection is in range or possibly plus or minus 2 to 3Hz or even higher sampling frequencies. Over a time period the average frequency may be 50 Hz. But within that time period the frequency will fluctuate. This is generally due to interference in the wireless environment. Power management in devices and its impact on data capture. At best we can say is that the data communication and collection is “probabilistic.”

Making sense of data capture that is probabilistic and fluctuates in conjunction with data that is captured with a more or less rigid time clock, and with other data the streams at even much different frequencies requires moderation in post processing of the data as well as in analysis.

Many devices have an internal buffer to collect some data in the event that the data transmission is interrupted by radio frequency interference. In these cases, the data transmission will be dumped to the software data collection with more or less regular device clock times, but the system clock may have significant gaps. The system clock times of the record may appear with very irregular intervals. This can be compounded by drop out of data points. Within the parameters of acceptable data sampling, the researchers will need to define specific acceptable ranges of data loss.

Data capture and format:

One consideration is how the data is captured. Writing data to a file in real-time incurs a cost in CPU compute cycles, and in delays in data capture. The solution to this problem is to record the data stream into random access memory where the time to write each data point is minimized. Then at the end of the capture session, process this data into a readable format such as XML or CSV. The format can be anything the software engineer chooses – a raw text file, or raw numerical data. The use of XML or CSV provides a source that can be accessed, with off the shelf software such as Excel, and easily can be accessed via scripts in MATLAB. To answer, XML or CSV are preferable the research team should consider how data is structured in these two formats. CSVs are defined by the data format as a flat structure. It can also be used with other applications since it does not require much technical skill to access files such as Excel. A further benefit is that CSV is significantly smaller than XML, which requires a lesser computational capacity. Recommended reading on data formats can be found in Stack Overflow blogs such as <https://stackoverflow.com/questions/1820129/when-and-why-is-xml-preferable-to-csv>. Another useful resource is <https://www.formtoexcel.com/blog/csv-vs-xml.html>.

6. Considerations for team-based development of research tools – user interface and interaction strategies

The system examples, Motion Tracker and HiPOP are perhaps the most ideal interface and interaction strategies. They require nothing of the consumer and react autonomously to the human, providing a meaningful response even before the human apprehends that they are being served by the system. Murray refers to the strategy as the “companion model”⁴⁸ with “synchronization through accompaniment.” Many apps used in social media or in portable device are examples of Norman’s concept of the “information appliance”⁴⁹ in his seminal 1999 text, *The Invisible Computer*. In this envisioning of a future computing Norman’s concept is for disrupting the personal computer with overly burdensome reliance on expert knowledge with simple responsive and feature rich yet hidden or transparent interactions. With the advent of functional AI systems, we may yet see feature rich, hidden or transparent applications as the norm for many applications we use today. An example of what may be possible was presented in Project Milo⁵⁰, a collaboration between Microsoft and Lionhead Studios running on an Xbox 360 console. The project was a



demonstration to showcase the capabilities of Kinect as a “controller-free” based on depth sensing and pattern recognition technologies. Milo is an example of emergent behavior of a virtual character. He learns, adapts, and adjusts his behavior to the cues given to him by the human actor.⁵¹ Milo, an AI driven character, learns and grows “emotionally” through interacting with human. This project, like IBM’s earlier Deep Blue chess-playing expert system was shelved and not released as a consumer product. However, we can see the ⁵²results of the research filtering out into other functional systems. These are now implemented as AI companion to search in browsers and in other applications.

The reason we can consider such interaction strategies the most ideal is that they require no active response from the participant. Indeed, the human gaining or acquiring accompaniment needs to do nothing other than to exist.

We have two extremes in systems to consider for the design of software and interfaces. At the extreme expert level software, the researcher writes and executes software to collect and to process data for specific needs. In these cases, the need for an interface is minimal, and in many cases, unnecessary. Many researchers employ quasi-development platforms such as MatLabTM. In other instances, write their own custom software using sensors, and other devices to collect data. On the other hand, the extreme simplicity of companion apps also require no user interface, nor active interaction by the participants. The app or device simply collects cues or data from the participant and provides adequate response and meaningful information.

Yet, most of the software needed for research applications exists between these two extremes. The interface is less of a concern the closer and more expert the user is to the process. If the user is a chemistry student using an interactive tutorial that simulates a chemical reaction, then the structure of interface and the interaction strategy must provide appropriate affordances. These considerations are more important, depending on who is responsible for data collection in research environments. Graduate students may often be running experiments, and data collection sessions. In these cases, the need for clear and understandable interfaces and interactions is evident. Since this paper is intended for audiences in the research domain, we can focus primarily on systems that an academic researcher needs to put together for their data capture in their study. Devices that are already in the marketplace have undergone significant design and testing both for usability and utility. There are considerations that a UI designer and Software Developer can raise that will be valuable to these projects. As stated above, working in team-based projects or outsourcing design and coding requires some knowledge of what the other stakeholders are doing and what skill sets they bring and

⁴⁸ Ibid. Janet Murray, *Inventing the Medium - Principles of Interaction Design as a Cultural Practice* Chapter 12, The MIT Press

⁴⁹ Don Norman, *The Invisible Computer: Why Good Products Can Fail, the Personal Computer Is So Complex, and Information Appliances Are the Solution*. MIT Press, 1999

⁵⁰ <https://www.techradar.com/news/gaming/microsoft-says-molyneux-s-milo-is-only-a-tech-demo-699668>

⁵¹ http://www.ted.com/talks/peter_molyneux_demos_milo_the_virtual_boy.html

⁵² <https://www.ibm.com/history/deep-blue>

how to effectively communicate across the discipline divides. In the initial discussions, the UI designer will ask for clear directions on what the operator of the system needs to see and what they are expected to do.

However, development is much more complex as one needs to write fully code-based applications using programming environments such as Visual Studio in a high-level programming language and a front-end interface built with Windows Presentation Foundation XAML UI design scripting, or Windows Console. (Universal Windows Platform is likely to be deprecated.) One can still use WinForm in Visual Basic, Forms UI and Console UI are both ugly in the opinion of the author. Nor do these lend themselves to important considerations of an effective UI – affordance and flow. These considerations are of utmost importance and are part of the recommendations provided by this paper.

The benefit of WPF and XAML for developers and UI designers familiar with HTML/CSS/Javascript web development is that the syntax and functionality of XAML is similar enough to allow easy migration. Microsoft provides GUI based XAML development package, Blend and it is most likely the UI designer will work with a dedicated software engineer for display of content and the interface.

Material Design⁵³ in XAML provides a rich set of interface elements, much like BootstrapTM provided for web development. Included are interactive buttons, plates, sliders, icons, both as SVG and font icon types. Material Design is also customizable – allowing for unique interfaces design for various “specific” audience. It can accommodate everything from the staid and straightlaced traditional look and feel to the street-cred skateboard avant-boufant styles.

Microsoft’s Visual Studio allows for direct hacking of XAML code or design via a graphical user interface with the integrated Blend component. Microsoft also acquired Xamarin that produces an open source software platform. Xamarin extends the .NET developer platform with tools and libraries specifically for building apps for Android, iOS, tvOS, watchOS, macOS, and Windows (UWP)

⁵³ <http://materialdesigninxaml.net/>

Most likely there will be requests for site visits and observation. Observation is expected as well in the testing and refinement phase.

This is an indispensable section of the development of software systems. Often, preconceived notions of how someone will interact with the system will cloud the vision, and impact of how affordances in the system are perceived by the non-expert. In this case, anyone not familiar with the software is a non-expert.

One method to alleviate the preconceived notions of development team is P.o.P. – prototype on paper. By designing the interface on paper and testing prior to creating digital interfaces.

Specifications phase for user interface:

User interface design and testing

- Flow, affordances and sequences of actions

- What data needs to be visible in capture time

- Post process reliability and evidence in successful data capture in sessions - ??

- Who are the users – MDs, expert level technicians? Training of operators

- Clarity of UI elements and affordances.

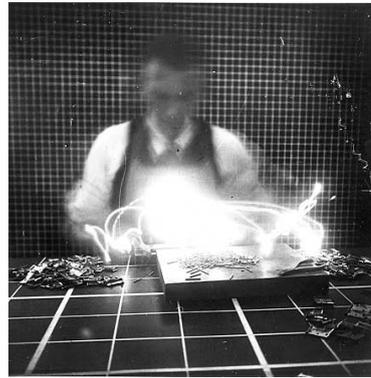
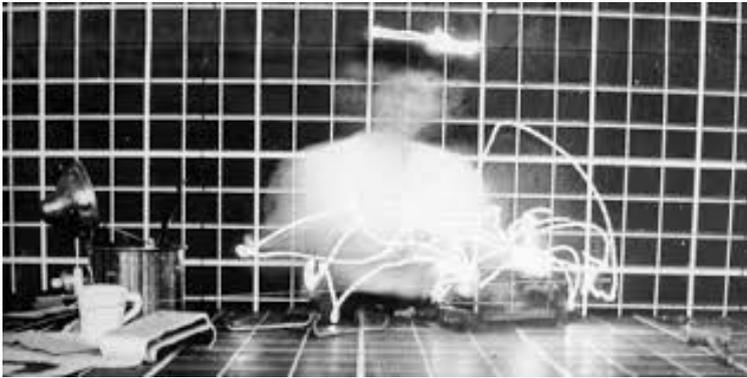
- Observation in session, adjustment and refinement of UI and flow.

GE EKG

60hz. 12 data points turn-key windows 10, dedicated card set for data collection.



The systems designed to maximize effort and work can be analyzed for ways to increase usability, increase effectiveness, and to create more ergonomic and efficient actions. This is the beginning of the user centric design processes. However, the effort of early researchers looked to understand **how to better adapt human actions to the systematized processes** of the assembly line and other mechanized processes.

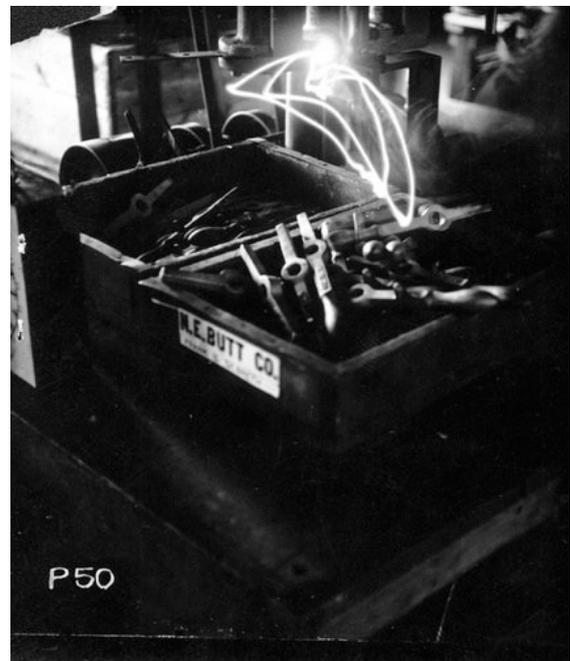


Gilbreth's motion studies

https://en.wikipedia.org/wiki/Time_and_motion_study

In applying Motion Study method to work, Gilbreth and his successors found that the key to improving work efficiency was in reducing unnecessary motions. Not only were some motions unnecessary, but they caused employee fatigue. Their efforts to reduce fatigue included reduced motions, tool redesign, parts placement, and bench and seating height, for which they began to develop workplace standards. Gilbreth's work broke ground for contemporary understanding of ergonomics.

Part of this research studied how to have worker's motions fit the process or mechanization.



$$g(x, y) = \frac{k^2}{\sigma^2} \cdot e^{-\frac{k^2(x^2+y^2)}{2\sigma^2}} \cdot (e^{ik \cdot \begin{bmatrix} x \\ y \end{bmatrix}} - e^{-\frac{\sigma^2}{2}}), \text{ where } k = \begin{bmatrix} k_v \cos \varphi \\ k_v \sin \varphi \end{bmatrix}, k_v = 2 \frac{v+2}{2} \pi$$

Figure 11: Formula for processing Gabor Bank filters for earlier mentioned Emota v3.0™ software.

The formula below in Figure 11 processes for classification of Gabor filters for facial expressions resulted in a significant amount of code. Gabor filters are implemented to derive orientations of features in the captured image using pattern analysis. The Gabor filters enable a more accurate positioning of graph vectors in an “elastic bunch map graph” that is aligned with facial features.⁵⁴

Sampling frequencies of devices used for data collection. System clocks on devices – is there a clock? Can it be reliably used – data collection in wireless devices – probabilistic data transmission. Interference in the wireless environment. Power management in devices and its impact on data capture.

Synchronization and reconciliation of sampling frequency in real time vs post capture re-processing.

Operating systems – system clock in Window, vs Device clocks.

Multithread processing – Invoking commands in Windows, never happens simultaneously. Reconciliation of system clock time commands vs device clock responses.

Processing time to post data – buffering and file dump on end of data capture.

When and Why is XML preferable to CSV?

CSVs are defined by the data format as a flat structure. It can also be used with other applications since it does not require much technical skill to access files such as Excel and PowerPoint. A further benefit is that CSV is significantly smaller than XML, which requires a lesser computational capacity.

<https://www.formtoexcel.com/blog/csv-vs-xml.html>

how a CPU works: <http://www.buthowdoitknow.com/> See the Book: <http://amzn.to/1mOYJvA>

Machine learning,

IoT device interoperability – benefits

⁵⁴ 2015 Pensyl W., Min, X., Song S., Facial Recognition and Emotion Detection in Environmental Installation and Social Media Applications Encyclopedia of Computer Graphics and Games <https://doi.org/10.1007/978-3-319-08234-9> = 978-3-319-08234-9

CR Categories: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems – Artificial, augmented, and virtual realities; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism – Virtual reality

Biography



Russell Pensyl (MFA 88, BFA 85) is an American media artist and designer. Pensyl’s current work includes the creation of location based entertainment several areas of technology in the application of content delivery in environmental spaces including emotion detection, facial recognition, positioning and localization, gesture recognition. Pensyl is a noted pioneer in mixed and augmented reality, creating one of the first integrations of mixed reality in theatrical a production. Pensyl was a finalist for the 2021 Premio Arte Laguna in Venice, Italy., and exhibited in the Heaven and Hell exhibition in Chicago IL, the 2020 The International Society of Experimental Art, Calgary, AB, Canada, the 2020 Altered States, National Exhibition of American Art, Pleiades Gallery in New York. In 2011, his installation “subtle presence” was included in the Sarajevo Winter Festival, In 2008, “The Long Bar” was Invited into the SIGGRAPH Asia Synthesis – Singapore. Pensyl's work has been included in the Shang Hai Biennial, SIGGRAPH USA, the Machida Museum of Art and many other exhibitions.

