

Fighting Human Error Using Visual Programming

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Abstract— When any catastrophe happens there must be a question about human factor or human error. Despite his\her intelligence, human is the main reason for huge amount of problems. There are too many factors that affect human's ability to do the job in the right way. It is impossible to control all these factors to prevent the human's error. However, there are techniques and tools that can be used to help the human makes as few errors as possible. As the computer is an important tool in human's day-today life, and human needs it all the time to do tasks such as, control important operations, this work is devoted to show how visual programming components can be used effectively to minimize human error while he\she is using the computer.

Keywords-component — Human Computer Interaction, HCI; Visual Programming; Visual Studio; styling; Graphical User Interface, GUI

I. INTRODUCTION

Whatever experience the human has, he/she may make mistakes because of many reasons related to the conditions of workplace that he\she works in, the human's body and its abilities and weaknesses, and the tools that human uses to do the job. Because computer has intruded in all aspects of human's life, this paper concentrates on the computer programs and how they can be developed in such way that helps user avoid as many mistakes as possible. It presents an overview of some programming tools and their properties to show how they can be used to help employees who uses computers make less mistakes. To be more specific, Visual Studio Integrated Development Environment (IDE) is used to present programming techniques and tools that can help fighting human error.

II. ERGONOMICS AND HCI

A. Definition and Functions

To solve the problem of mistakes that occur during the use of the computer programs, software developers and hardware manufacturers need to understand, not only computer programs and hardware, they also need to understand the human himself. There is a scientific field that is interested in studying human and his\her interaction with the elements of the world around him\her. It is called Ergonomics. The International Ergonomics Association (2000) defines Ergonomics as following "Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and

methods to design in order to optimize human well-being and overall system performance" [1]. It also determines the main goal of Ergonomics as "Ergonomists contribute to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people."

Human Computer Interaction (HCI) is a scientific field that studies how people interact with computers and to what extent computers are or are not developed for successful interaction with human beings [2].

B. The Four Aspects of HCI

Based on HCI literature, for example [3, 4], there are four aspects of HCI that program designers have to pay attention to, that affects the human's ability to better use the computer and software. These aspects are (see figure 1):

1. The human himself.
2. The computer.
3. The GUI with witch the user will interact with.
4. The environment in the workplace.

All these aspects affect the user and play an important role in his\her efficiency while he\she is working on the computer. The human's personal and physical characteristics have a direct effect on his\her ability to do the job. Graphical User Interface (GUI) also plays critical role in HCI because making easy, clear and attractive GUI helps decreasing the amount of mistakes that the user could make while using the computer program. The environment in the workplace is also very important. The furniture such as the chair, the disk, the light and the air condition such as temperature play an important role in user's health and comfort that affect directly the abilities of the user and how he\she does the work.

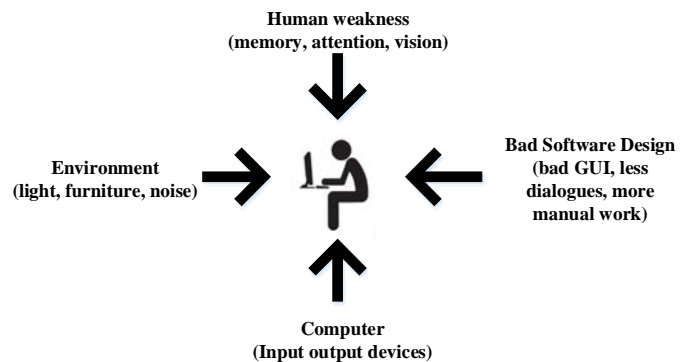


Figure 1. Forces acting against computer user

C. Approaches to study human error

There exist two approaches to view problem of human error [5]:

1. The person approach - focuses on the unsafe acts – errors and procedural violations – of people. It considers a person is responsible for errors. Followers of these approaches tend to treat errors as moral issues, assuming that bad things happen to bad people
2. The system approach - The basic premise in the system approach is that humans are fallible and errors are to be expected, even in the best organizations.

The main advantage of the system approach that it focuses on helping person not to make mistakes by providing best tools to help him\her stay focused and make less mistakes even if something else is distracting him\her.

In this research the author builds ideas based on system approach. The idea is to show how visual programming (VP) components can help fighting against human error when using computers to help doing the job.

III. REASON FOR USER'S ERROR

Based on Dr. David J. Smith exist the following main factors that cause human error [6]:

1. Environmental factors – these include the light in the work place, furniture, air condition, and external objects outside the workplace that may cause employee discomfort or confusion that lead him\her to make mistakes.
2. Intrinsic factors – these include selection of individuals, training that human had and the experience that he\she gained through long time of work.
3. Stress Factors – these include two aspects: personal stress that maybe caused by some personal problems such as divorce, moving to live in new place, death of someone too close; circumstantial that maybe caused by some accidental troubles such as new task that costs too much if failed, necessity to meet some deadlines, problems with tools etc.

For the goals of this research the following reasons for human error has been taken in consideration based on Marguglio's Taxonomy of Human Error Causal Factors [7]:

1. Attention – something may distract user causing losing of concentration that may cause making mistakes.
2. Slow reaction – a user may have slow reaction that may cause responding to stimulus too slow that may cause serious effects based on the importance of user's fast response.
3. Forgetfulness – a user may have problems with memorizing series of steps or values that are needed as input to the program to do the job.
4. Bad training – unqualified user may make mistakes because of the lack of good training and skills.

5. Stress – working under pressure many users do make mistakes that may have serious consequences.
6. Vision – low light, bright light, bad GUI can affect user's ability to perceive visual data causing bad decisions and mistakes.
7. Uncomfortable environment – chair, desk, computer position in the workplace may cause discomfort and that may lead to mistakes.
8. Carelessness – user may not care for the job if he\she lost interest in its success. As a result he\she may make mistakes because of losing the purpose of the job.
9. Boredom – lack of excitement maybe a reason for mistakes.
10. Uncertainty – sometimes doing some work a user maybe uncertain that he\she did everything right, so he\she may try to repeat the action like pressing the button again what may cause mistakes by repeating action or annoying others.

All what is introduced before shows that it is impossible for human not to make mistakes because there are too many factors affect his\her right interaction with elements of the system. Even if the user has good training and knowledge, best furniture in the workplace, and best GUI, there is still a problem that no one can control his\her mental and body health. Software designers and developers have to take in attention this fact. In fact, developers of IDEs for building computer programs have provided software developers with huge amount of tools that they can use to build easy-to-use computer programs. Following is a view of some components of Visual Studio and how can they be used to fight human error. Information in the following sections is based on [8, 9].

IV. VISUAL PROGRAMMING VS. USER ERROR

The following sections introduce some techniques and tools that can be used effectively to build computer programs that help avoiding user errors.

A. Design Techniques

There are some advices about techniques that can be used to organize controls on the window to help fighting against early mentioned reasons of human error. Following are some of them [4]:

- 1) Grouping.
- 2) Structuring.
- 3) Ordering.
- 4) Decoration.

Following is an explanation for these techniques and how Visual Studio helps realizing them.

1. Grouping: if controls are connected by some properties or functions they must be grouped somehow together so that the user can concentrate better and his\her memory prepare the needed data for inputting based on the main idea of the group. This will make the user input data faster with less mistakes. For example, designing a form to work with client's data it can

be noticed that such data as: Client's Number, First Name, Second Name, Age and Gender are connected by the main idea that they describe personal. So, they must be somehow grouped together. Other data about identification card of the client such as: Card Number, Type, Issue Date, Expiring Date, Place of Issue and so on, all can be grouped in another group.

Software developer can group elements on the Form of Visual Studio project using the following visual components called Containers: Flow Layout Panel, Group Box, Panel, Split Container, Tab Control, and Table Layout Panel.

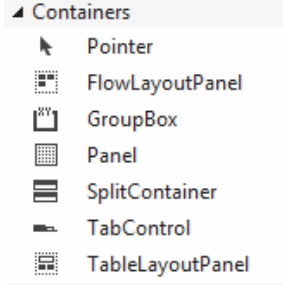


Figure 2. Containers to group visual components

2. **Structuring:** grouping controls developer may notice that some groups are related in a structural manner. In the example mentioned in the previous section there are three groups of client's information: personal Information, identification card information, address information. All these information is about the client. Other information about the Product that the client orders and about the order itself can be grouped in separate group. Order in its turn has relation with the client. All these relations can be shown as a hierarchy or network relation to ease the understanding of the relationships between groups.

Using grouping components of VS with the appropriate positioning of each group under the master group helps the user identifying each group and work with groups more efficiently. Visual Studio provides visual components that can be used to show the relationships between program elements such as Tree View.

3. **Ordering:** in many cases data have to be entered to the software in exact order. Software designer has to order controls to help user input data correct with no mistakes in ordering. For example: turning to Database Design there is a function that Database Management System (DBMS) provides users with so called "enforce referential integrity". If database developer enforced referential integrity, then the data must be entered in a specific order beginning with the Master Table then the Slave Table. That means the controls on the form must be grouped, structured and laid in the right order so user will not make mistake inputting data in slave table first what causes DBMS to show scary message that he/she may not understand about the data integrity. The following figure shows an example of such message.



Figure 3: Error message about referential integrity violation (source: <http://www.informit.com/articles/article.aspx?p=761837&seqNum=4>)

Tab Index Property: Usually, the key "Tab" on the keyboard is used to move from one component to another. Visual Studio provides software developers with an interesting and important property that helps ordering the process of transmission between the components using Tab key. It is called "Tab Index". This property gets an integer value that determines the order of the transmission within visual components on the form using the Tab Key. This property also helps user to work comfortably with software by offering him/her to avoid using the mouse to move from one control to the other. That makes inputting data faster, easier and more comfortable fighting against errors, stress and slow reaction that is related to the use of the mouse to move across the components.

4. **Decoration:** decoration can be implemented using many ways: separating lines, boxes, colored background, font style, images etc. [4]. Visual Studio provides many tools to help realizing this technique, such as: Background and Foreground Colors properties of the components, Image property that allows loading various types of images that can be used as a decoration background attracting the users and differentiating between visual elements and groups, and Picture Box that allows adding a picture to the Form to be used as a background picture for other components or to add more information..

Decoration technique is heavily used in GUI of computer games, websites and video-audio media players (Fig. 4).

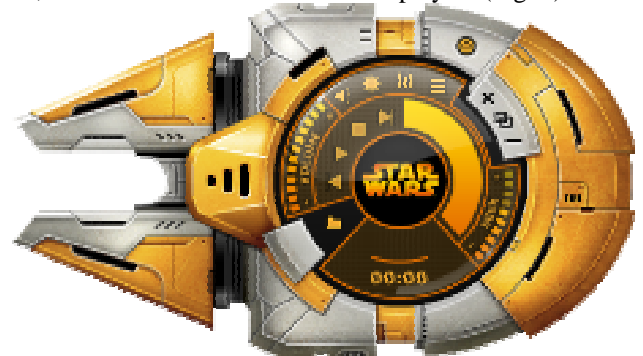


Figure 4: Decoration in GUI of Winamp media player (skins) (source: <https://oliviofarias.blogspot.com>)

The following table shows techniques for organizing visual components and the Visual Studio's components and their properties to realize them.

Table 1: Techniques for organizing GUI and VS components

Technique	Visual Studio Elements
Grouping	Flow Layout Panel, Group Box, Panel, Split Container, Tab Control, and Table Layout Panel
Structuring	Tree View component and organizing components in groups in some hierarchy.
Ordering	Determining ordering using Tab Index Property
Decoration	Background and Foreground Colors properties, Image property, Picture Box

B. Visual Components against User Error

The following sections introduce some of the most popular visual components of Visual Studio and their properties and how to use them to build computer programs that help fighting human error.

Button

Providing info about the job: First of all, looking at the visual component Button software developer and user can notice that it has a text label on it. User needs to know what this button can do. That is why button has a label so the programmer can write on it a text that shows its function. User read this text to determine what it can do.

Tooltip: On the other hand, programmer cannot write much text on the button, usually because the window is full of other components and other buttons. So, what if the text is too small to explain to the user what he/she can do with it? Visual Studio developers offer another component "tooltip" that enables all visual components on the current form to have a tip that appears on the component when the mouse cursor is moving on it. It shows a short or long text that can be used to explain what the Button can do without adding physical component that may make the form more crowded. It can be added to the form then developer can write the tip text in the property of any component on the form that is called "ToolTip on toolTipX" (x – number of component) [8, 9].

Attraction, explanation, decoration: another problem that is connected with humans that some users may prefer images to texts; other users may not be able to read the text. How to help such users? Visual Studio offers a property of the Button that is called "Image". Software developer can use it to add image to the button to use it instead of the text on the Button. This helps user in many ways, such as: images can be attractive that users may like them which may eliminate the boredom and carelessness; images better and faster deliver information to the users visually; images may show much more information than usual text (a picture is worth a thousand words (idiom)).

Fighting uncertainty: Buttons show interesting way of interaction with the user. Human in nature can be doubtful if

there is no reaction from the object he is interacting with. That makes him/her think he/she did not do the interaction right. As a result, the user may repeat the action what, in turn, may cause undesired results. The developers of Button component provided the button with default reaction that shows the Button as if it was pushed down to make user be assured that he/she really pressed the button. This prevent the user from pushing the Button again because doing that may cause repeating the action again what is usually not desired. For example: repeating the operation of withdrawing 1000000 dollars from client's account while the employee has to do it once will have horrible consequences.

Another way to fight uncertainty by adding sound that is played each time user presses the button. That is what is happening when user press anything on the windows of operating systems or mobiles' keyboards.

Enabled: Interesting property that help preventing human error. It is another way to prevent the user from pushing the button again by disabling it then enabling it again when necessary. This can be realized using the property of the button that is called "Enabled". It takes one of two values: true or false [8, 9].

Tab Index: Property of the Button that is used with other components too. It allows the developer to assign a number that defines in which order this component will be the current component to work with when the user presses the key Tab to move throw visual components on the window. Using this property for all components helps the user move through components in such order that helps him/her faster input data and process them as needed.

Finding the way back: user may be distracted for many reasons, then when he/she looks back at the window again he/she may forget where he/she was. All visual components has interesting default way to show up. They usually have colored boarder when they have the focus. That helps the user all the time know where he/she stopped on the window.

Label

Label is one of the most widely used components. It has an important function that is connected directly to the task of preventing human error. Label is used for titles that explain to the user what he/she can input in the inputting fields. It does not allow users to alter the text on it. This default property makes the Label an essential component in any form. For data input exists other components that are viewed in the next parts.

Border Style: Property helps with decoration. It changes the border style of the component that helps user better distinguish it among others.

Text Box

Text Box is one of the most used visual components for data inputting. That's why it is crucial for software developers to know how to use it right. There are many properties that have to be used carefully to control data inputting to prevent user errors that may affect the whole system. Following are some

special properties of this component that Button does not has and how they help fighting user error and make work with software easy and interesting.

Character Casing: sometimes user needs to enter abbreviations that has to be in capital letters. This property helps the software developer to enforce component to accept only capital letters if needed what makes inputting abbreviations much easier and releases the user from necessity to press Caps Lock key while inputting abbreviations.

Read Only: a property that can be used to show data so that the user cannot change them preventing the user from accidentally changing important data that is only for reading.

Accepts Return: this property enforces the component to accept the return key. In the case of text box that uses only one line the return key activates the default button for the form. This can ease user's work with the form eliminating the time spent to move the mouse cursor to the default button what accelerates user's actions.

Masked TextBox

Another component that is really useful for fighting user error is Masked Text Box. It helps creating mask that helps the user inputting formatted data like date as it is required. That also helps fighting the problem of using different format of data by employees in different places who works with the same system. Example of the use of Masked Text Box is the window to input the IP Address in windows OS.

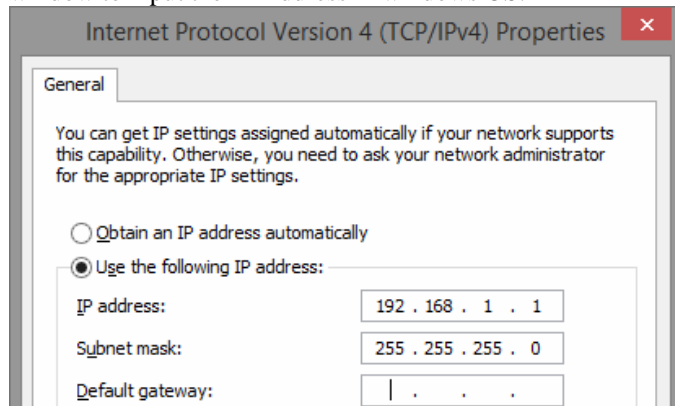


Figure 5. The usage of Masked Text Box to input IP address and DNS Server address in Windows

Combo Box

Fighting slow inputting, errors and stress: this component offers the ability of choosing a value among collection of values provided in a drop down list. This ability is very useful against many reasons of user errors. Choosing a value instead of entering it helps to solve the following problems:

- Saving time.
- Decreasing writing errors by offering previously prepared correct values.
- Decreasing pressure on memory because the user needs to choose not to remember how and what to input.

All these help decreasing dramatically the chances of having stress helping the user doing the job relaxing and enjoying it.

Autocomplete Property: Is a very important property and service that Combo Box provides to the users. Choosing the values is really useful service, but it is also slow operation when the component has too much items in its list. The Autocomplete property offers faster way to input data by showing the items that matches the current letter that the user is inputting then the user can just choose the needed value among others with matching letters without the necessity to input the whole word.

Radio button

A component that offers the ability of choosing exactly one value among many others. This ability is crucial when the user has to choose only one value among many others and it is considered incorrect to choose more than one. Example of that is choosing the gender of the client. Besides, it saves time offering the user to choose value not to input it.

Check Box and Checked List Box

Check Box is a component that allows multi choices at the same time. It saves time and accelerate the process of inputting many values allowing user to choose values not to enter them. Check List Box offer the same ability but with default good ordering and organization of many check boxes.

Progress Bar

This is an important component to fight against uncertainty and boredom. It shows animation in a long bar that grows filling it as the operation such as copying files is continuing. If an operation needs too much time to be finished the user may think that it failed or will never be finished if he\she gets no feedback about its state. Progress Bar is a component that helps fighting those bad feelings that can affect the correct work of the user.

Using the component Time with the component Progress Bar to show how much time elapsed until the operation finishes helps fighting boredom and uncertainty that may be caused by long operations.

C. Fighting the problem of crowded window

Usually, there are a lot of operations that the user needs to fulfil. Devoting a button to every operation is unreal task and solution because doing that makes the window very crowded. Crowded window causes the user to have difficulties with memorizing all the components and finding needed component to run the operation. This also makes the program unattractive to the users. Following are some components that can help solving the problem of providing as much functions as possible without the necessity of adding too much components to the window.

Context Menu Strip

Provides easy and fast access to huge amount of operations that can be realized on a specific component what eases the work with the window without making it crowded with controls. It allows organizing and grouping the buttons to call

operations in some hierarchy which eases the process of searching a command among many others [8, 9].

Status Strip

An important and very useful component is Status Strip. It provides predefined components that appear on a bar at the lowest part of the window to provide user with important feedback about the state of the program's operations. It offers four components (Visual Studio 2015): Status label for static text about the state of an operation or the window; Progress bar to show the progress of an operation that needs long time to be finished; Drop Down Button and Split Button to help easy and fast calling for some needed operations.

Tool Strip

Tool Strip allows providing users with visual components on a bar on the top of the window. Providing visual components on Tool Strip helps user getting fast access to the main functions or functions that are frequently used saving time and energy.

D. Other useful abilities

Following are some other abilities that can help against user error.

Default Values. These are values that are giving as initial values. These values are very useful to make the process of inputting data faster and easier in many cases. For example: taking to the consideration that usually the clients of the company will be people from the same country and the same city the company exists software developer can use the names of the country and the town as default values what may shorten and ease the process of filling clients data in most cases.

Calculated Values

In many cases software developers can save time and energy of the user by using calculated values to provide data without the help of the user. Examples of such values are: age that can be calculated by using the birthdate subtracted from current date. Total price and total price with discount are other values that must be calculated automatically to save the user's time.

Sound

Attention: One very important characteristic of the sound that it can be received from any direction. That's why showing a warning message to the user should be conveyed with a sound. The user will be warned about the message wherever he/she is looking at solving the problem of attracting the user's attention. Sounds can also played at the end of any operation to inform the user that the operation is finished even if he/she is far from the computer.

Sound has very important advantage against vision. Sound is carried by waves that spread out as they travel, covering a larger and larger span until the sound has dissipated beyond our capacity of hearing. This property of sound makes human hear the sound without seeing its source [10] (see fig. 6). The ear can get the sound from any direction without the need for

the ear to be directed to the sound. While for vision to happen the human needs to have his/her eye directed to the object to see it because the eye has a limited angle of view (see fig. 7) [11].

Visual Studio provides software developers with many tools to play sounds such as the class System.Media.SoundPlayer to play wav sounds when needed.

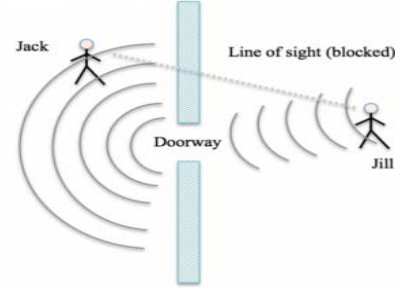
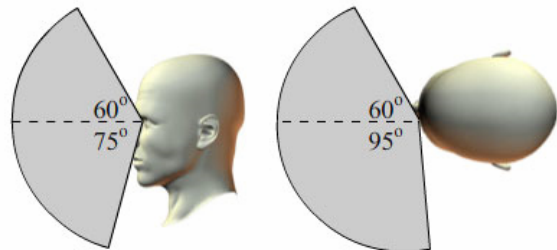


Figure 6. the sound can be heard even if the eye cannot see the source



Physclips www.animations.physics.unsw.edu.au

Figure 7. the vision has limited angle of view (source: <http://www.animations.physics.unsw.edu.au/jw/light/eye-performance-compromises.htm>)

Boredom: Sounds can be played while long operations is running to help the user relaxing fighting against boredom and stress. But, there must be an ability to shut the sound down if the user would like to.

Uncertainty: Sounds also can be used to fight uncertainty. Playing a sound every time the user presses the button will help the user be sure that the button pressed and there is no need to repeat the operation.

The Function Focus

This function moves the focus from one component to another. Using it after the user finishes the inputting some data saves the time and accelerates the process of data inputting. For example, software developer can move the focus from one control to another by calling this function saving the time needed to move the cursor to the needed component.

The Event Key down

This is an event that happens when the user presses the button. It can be used to call some interesting functions such as Focus() to move focus from one component to another saving the time and energy of the user.

Showing Summary

Very important thing to do is to show the user a summary of the most important data he/she has inputted before saving

them permanently. This helps the user verify the correctness of his\her input before saving them permanently what helps fighting errors and uncertainty.

Dialogs

Every time the user calls an important operation the program should ask him\her if he\she is sure about it. This helps attracting the user's attention to the importance of the operation and help him\her concentrate more to make better decisions. Visual Studio offers many components to use for dialogs. They exist under category Dialogs. There are the following components [9]:

- Color Dialog - helps in choosing a color visually.
- Folder Browser Dialog – helps choosing a folder for some operation visually.
- Font Dialog – helps choosing the font when needed.
- Open File Dialog – helps choosing the file for uses in the program.
- Save File Dialog – helps choosing a name and folder to save work in a file.

Using these components releases user's memory from the need to memorize colors, fonts, folders names and so on. This accelerates the process of choosing a color, font or folder and helps decreasing the chances of mistakes when the user works under stress.

Time

Software developers usually shows how much time elapsed until the operation is finished. This helps with the problem of boredom and uncertainty about the continuing of operation. Visual Studio offer a component that is called Timer that can be used to control some operations using timer or to show time for operations.

V. CASE STUDY

Following is a program that is designed to show the usage of some of the previously mentioned tools and techniques to fight user's error. In the following program developer provided the user with the following services:

- Tab index – this property is used to make the process of moving across the components easier and in the right order without the using of the mouse.
- Combo boxes are used to help the user choose values rather than inputting them. With the Autocomplete property the time of inputting data has dramatically shortened.
- The Key-Down Event is used to move the focus from one component to another when the user presses the key Enter on the keyboard.
- The Masked Text Box is used to enforce inputting dates in a unified format.
- Author prepared text files that contain usually used data as input to be used for filling the Autocomplete Property of Combo Boxes used for First Name, Second Name, Surname, Country, Nationality and City. Taking to the consideration that the program is

used in Arabic country and the program is excremental there is a file for Arabic countries names, other file contains names of their capitals, a file for the most popular towns. For Passport Type the developer uses the Items collection of the combo box because it has few values to choose from.

- Calculated Values: The age is calculated using the Now function of the class DateTime to subtract from it the Birth date. Expiration Date of the Identification Document is also a calculated value from the date of Production.
- Tool Tip is used to explain to the user what to input when he\she needs help.
- Components has been separated in groups based on the object they deal with: personal data, personal card data and address.
- Auto input: when the user inputs the nationality of the client the program chooses the country base on nationality then prepares list of cities of the country to help the user choose the appropriate one. In the same time the values selected as the country and town is automatically inputted as default values for the place of the personal identification card taking to the consideration that usually the country and city of the client is the same place where he\she got his\her identification card.

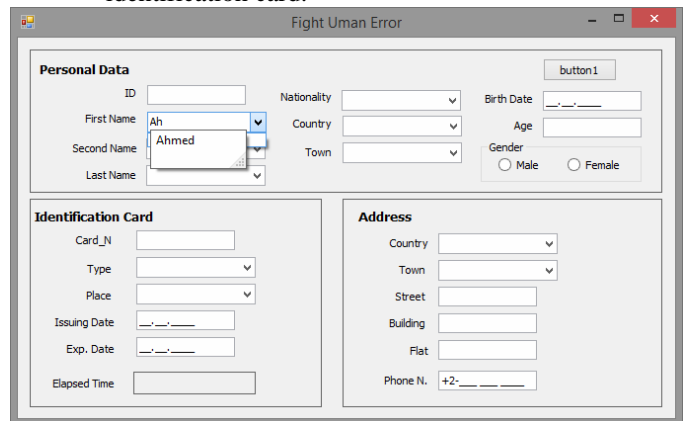


Figure 8. Combo Box helps choosing a value

Using the program many times to input data using the abilities provided by the program and many other times inputting data without using its abilities proved that those abilities help shorten the time of inputting data for one client from almost 3 minutes to almost one minute. Within some time the user can get used to the program that he\she can shorten the time of data inputting to less than a minute.

VI. CONCLUSION

Nobody can prevent the user from making mistakes while using computer programs because there are too many factors affect his\her ability to work correct. Stress, health, workplace environment, GUI, light at the work place, problems at home, problems in the country and so on. Software developers can use the tools and abilities that are provide by visual programming tools to help the user making as few as possible

mistakes. This can help fighting against human error during using computer which makes the work with computer easier, more attractive and more productive.

Following is a table that introduces in brief the reasons for human error and visual programming tools and techniques to fight them.

Table 2: Reasons for human error and techniques against them

Reason for Human error	Technique against it
Attention	Dialogs. Sounds. Lightened boarder around the component. Colors. Animated texts.
Slow reaction	The event Key Down with the function Focus to move focus to other component without the mouse. Calculated and default values. Autocomplete property of the Combo Boxes.
Forgetfulness	Reminders using timers or when some important operation runs. Choosing element from list of values that are built using Check Box, Combo Box, Radio Buttons
Bad training	Tooltip. Help files. Operations that fulfilled automatically.
Stress	Sounds. Colors. Calculated values. Operations that fulfilled automatically.
Vision	Special boarders' styles. Grouping and structuring using containers. Colors. Appropriate size of fonts. Appropriate light.
Uncomfortable environment	Ergonomically elements of the workplace
Carelessness and Boredom	Stimulus from the managers. Attraction with dialogs, images, sounds
Uncertainty	Sounds. Property of the components that is called Enabled. Changing the color of the text or the background of the component when the user moves cursor over the component or click it.

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