

An Object-Oriented Program for Matching Tractors and Implements

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Abstract— Proper matching of tractors and implements is crucial for maintaining high operational efficiency on the farm. An object-oriented program in Visual C++ was developed to predict the performance of tractor-implement system. The Brixius Model and ASAE Standards D497.5 were used to predict the tractor performance and implement draft respectively. A simulation subroutine in the program selects the optimum field speed that matches the pull provided by a tractor with the Draft requirement of an implement and displays some performance parameters of the tractor-implement system. Tractor and implement performance parameters such as field speed, drawbar pull, drawbar power, total implement draft, field capacity, and actual operating hours are predicted for the selected tractor-implement system. The program is appropriate for farm machinery management, educational and research purposes. It is user-friendly and could be run on Windows desktop with or without Visual C++ environment. The databases of the tractors and implements could be edited and/or updated to suit the required task of the user.

Index Term— Tractor-Implement system, Object-oriented program, Draft requirement.

I. INTRODUCTION

In the past, misunderstood concepts and inappropriate selection and use of certain mechanization inputs (mainly tractors and heavy machinery) have in many parts of the world led to heavy financial losses and lowered agricultural production as well as contributed to environmental degradation. In many developing countries, ambitious politically-motivated tractor schemes have often become a burden to the national budget and the farming community rather than being a productive input [1]. A careful approach to matching tractor and implement can increase efficiency of operation and farm profitability. When they are correctly matched, the results include reduced power loss, improved operating efficiency, reduced operating costs and optimum use of capital on fixed costs [2]. The matching process of tractor and implement is something that farmers often do "sub-consciously" with much dependence on their experience. While this approach may enable the farmer to carry out the intended operation, the system may not be operating at optimum operating efficiency. Therefore, for improving the operating efficiency, it is important that both units be selected in such a way that the power generated by the tractor is fully utilized. Grisso *et al* [3] claimed that for proper matching of tractor and implement it is necessary to carry out the following:

- (i) Predict the draft and power requirement of the implement taking into consideration factors such as depth and speed of operation, implement width and soil condition.
- (ii) Predict the tractive capability and the drawbar power that can available on the tractor by considering factors such as vehicle configuration, weight distribution, ballasting, tractive device type, and terrain conditions.

Some researches have been carried out to determine the draft and power requirements of tillage implements in various soils. Several published reports were reviewed by [3] and they deduced that the implement draft is a function of implement width, operating depth and speed. The effect of speed on implement draft depends on the soil type and the type of implement. Draft force has been severally shown to increase significantly with operating speed and the relationship ranges from linear to quadratic. Draft also depends on soil conditions and geometry of the tillage implements [4]. Grisso *et al.* [3] reported that Harrigan and Rotz [5] proposed a simple function to predict the draft force of tillage and seeding implements. Reference tables were also developed by them for soil and machine specific parameters. These tables and mathematical expressions were adopted by the American Society of Agricultural Engineers to revise the ASAE standard for Agricultural Machinery Management data as part of ASAE D497.5 ASABE [6] to predict the draft on tillage implements for different soil types.

The traction model developed by Brixius [7] formed the basis for majority of the studies to predict the tractive performance of power units using graphical methods, templates, and software programs. Al-Hamed *et al.* [8] used spreadsheet in predicting the performance of 2WD, 4WD, and MFWD tractors equipped with bias-ply and radial tyres in agricultural soils. Al-Hamed and Al-Janobi [9] performed the same task using a Visual C++ program. According to Grisso *et al.* [3] several studies have developed programs to assist in the decision making process for the selection and management of machinery and to make the different operations cost and energy-efficient. Only a few researchers have succeeded in developing appropriate procedures for matching tractors and implements based on estimated power requirement and power availability, with consideration to the terrain and equipment factors. Spreadsheet was developed by Grisso *et al.* [3] for matching tractors of diverse configuration with various implements or the other way round. Presently, many researchers in various fields are involved in developing object-oriented programs, which are effective and easy to access. Most of the tasks in these

programs are executed in response to an event linked to an object. In addition to their importance in the software field, it is also necessary to develop such programs to service the educational and research needs in agricultural fields [9].

While the spreadsheet developed by Al-Hamed *et al.* [9] and Grisso *et al.* [3] were capable of matching various tractor and different implements, it was not as simple and user-friendly as the program developed in Visual C++ for the same purpose. Furthermore, the Visual C++ program developed by Al-Hamed and Al-Janobi [9] uses a simulation to arrive at a typical field speed for the tractor-implement combination. This final typical field speed depends on the initial choice of each of the tractor and implement. If the difference between the drawbar pull available on a selected tractor and the draft required by a selected implement is too large, the simulation will converge in a field speed that is out the range specified in ASABE [6]. In case of inexperienced user of such program, there is need to alert the user when the simulation will converge in a field speed that is not practicable. Furthermore, simulation program should be a fast and cheap method of understanding the field performance parameters of tractor system especially for students [10]. Hence, the need for proper guidance to the users of the simulation program.

The objective of this paper was to develop an interactive object-oriented program in Visual C++ to predict tractor and implement system performance. Specifically, the program calculates the draft requirement for a given tillage implements and performance of a selected tractor by accessing the corresponding databases containing the required information. It also performs tractor and implement system simulation to predict a practical operating speed (as specified in ASABE standards) suitable for the tractor-implement combination and the performance parameters of the system.

II. TRACTION AND TILLAGE MECHANICS

For a tractor-implement system, it is necessary to determine the implement draft requirement. Draft refers to the force required to pull an implement in the horizontal direction of travel. For seeding implements and minor tillage tools operated at shallow depths, draft is primarily a function of the implement width and the speed at which it is pulled. For tillage tools operated at deeper depths, draft depends on soil texture, tillage depth, and geometry of the tool in addition to implement width and the speed [9]. The models for predicting the tractive performance of tractors and draft requirements of implements available in Zoz and Grisso [11] and ASABE [6] respectively were used in the development of the computer model. The computer model for predicting the tractor performance was also based on Brixius model [7]. The following are the relationships developed:

Motion Resistance (MR) is expressed as

$$MR = GT - NT$$

(1)

$$GT = W \left(0.88 \left(1 - e^{-0.1B_n} \right) \left(1 - e^{-7.5sl} \right) + 0.04 \right) \quad (2)$$

$$NT = W \left(0.88 \left(1 - e^{-0.1B_n} \right) \left(1 - e^{-7.5sl} \right) - \frac{1}{B_n} - \frac{0.5sl}{\sqrt{B_n}} \right) \quad (3)$$

$$\text{Hence } MR = W \left(\frac{1}{B_n} + 0.04 + \frac{0.5sl}{\sqrt{B_n}} \right) \quad (4)$$

$$B_n = \left(\frac{CIbd}{W} \right) \left(\frac{1 + 5\delta/h}{1 + 3b/d} \right) \quad (5)$$

where:

MR = Motion resistance (N)

GT = Gross Traction (N)

NT = Net Traction (N)

W = dynamic wheel load normal to the soil surface (N)

CI = Cone Index for soil (kPa)

Sl = Slip (decimal)

B_n = dimensionless ratio

b = unloaded tyre section width (m)

d = unloaded tyre diameter (m)

h = tyre section height (m)

δ = tyre deflection (m)

However, values of CI and B_n for Agricultural drive tyres ($W/bd \approx 30 \text{ kN/m}^2$) on typical soil surface are given by ASABE [6].

$$\text{Total Draft, } D_t = D_f + MR_t \text{ (N)} \quad (6)$$

where

D_f = Implement Draft (N)

MR_t = Total Implement motion resistance (N)

$$MR_t = \sum MR \quad (7)$$

where:

MR = Motion resistance of each individual wheel supporting the implement (N)

The aspect of the computer model for the implement Draft prediction was based on the equation published in ASAE Standard D497.5 [6];

$$D_f = F_i [a + b(s) + c(s)^2] w d \quad (8)$$

where:

D_f = Implement Draft (N)

F_i = dimensionless soil texture adjustment parameter

i = 1 for fine; 2 for medium and 3 for coarse soil

a, b and c = machine specific parameters [6]

s = field speed (km/hr)

w = effective width of implement/machine (m)

d = tillage depth (cm) for major tools [but assume 1 (dimensionless) for minor tillage tools and seeding implements].

The Draft data for F, a, b and c are contained in ASABE [6]. However, for the implement of interest in this study, parameter values are included in the database of the computer model.

II. TRACTOR AND IMPLEMENT MATCHING PROGRAM

An event-driven, object-oriented, user friendly, application program was used for predicting the performance of tractor-implement system utilizing Visual C++ environment containing several windows that serve specific functions in the development process. After the development of the application, it was converted to a free-standing executable version so as to be able to run the

program directly on the Windows desktop, without starting up the Visual C++ environment.

The matching tractor and implement program mainly consists of two sections: menu and buttons. The program starts with an opening screen as shown in Fig. 1. The screen consists of a menu bar with options Task and Help and six buttons. The Task menu has the following submenu: New Tractor, New Implement, Simulate and Exit. The six buttons are: New Tractor, New Implement, Simulate, OK, Exit and Cancel. The New Tractor submenu and the New Tractor button are used to activate the window for adding the specifications of a new tractor to the tractor database. The New Implement submenu and the New Implement button are used to activate the window for adding the specifications of a new implement to the implement database. The Simulate submenu and the Simulate button are used to activate the Simulate window which is used to carry out the simulation process of matching tractor and implement as shown in Fig. 2. The OK, Exit and Cancel button are used to close the opening screen.

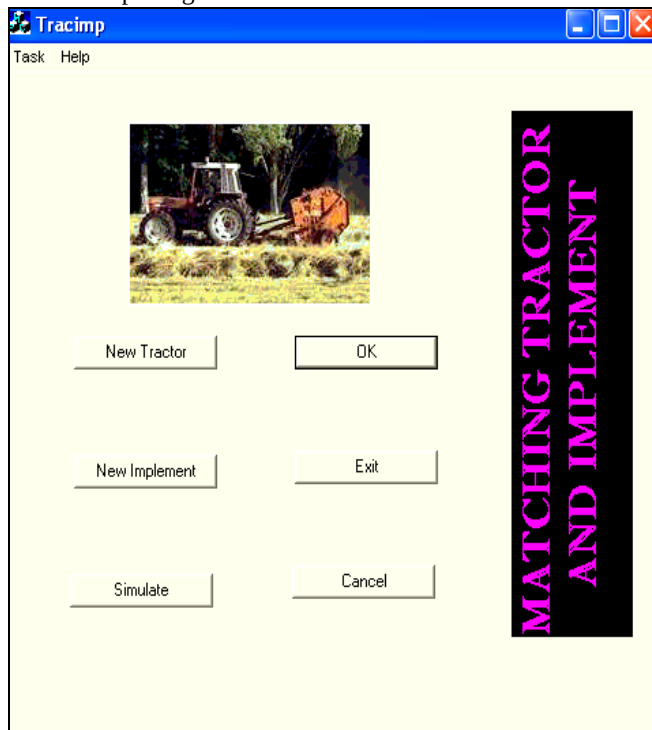


Fig. 1. Opening Screen of Matching Tractor and Implement Program

Fig. 2. Simulation Program Window

A tractor of a particular model can be selected from a tractor selection database, which contains a number of tractors manufactured by different companies and the corresponding model number. This database is linked to the tractor specification database. Once a tractor model is selected, the specifications of that particular tractor model are displayed on the simulation window and made available for the simulation program. Likewise, once an implement is selected, the specifications of that particular implement are displayed on the simulation window and made available for the simulation program. The user is expected to input the area and select the soil type on which the tractor-implement system is expected to operate.

The simulation part of the program to match a tractor and implement for optimum performance and predict the system performance parameters is done by clicking the OK button of the simulate window (Fig. 2). The simulation begins with an assumed maximum no load speed of 18 km/hr. This speed is adopted after considering 30% slip on the average maximum field speed range of 11-13 km/hr of most of the common field machines [9],[6].

The testing condition is whether the absolute value of the difference between the tractor pull and the implement draft requirement is greater than a tolerance of 0.5 kN [9]. For the first time the implement Draft requirement is calculated using an assumed typical field speed of 8 km/hr, which is approximately an average field speed of most of the common field machines [6]. It is higher than the tractor pull corresponding to the maximum no load speed. So the test condition becomes true and the maximum no load speed is decremented by 0.01 km/hr. Then the simulation is performed with the new reduced speed, keeping the implement Draft requirement value the same. This process is repeated until the testing condition becomes false. Then the implement Draft requirement is recalculated based on the actual speed found by simulation.

Finally, the program converges with a typical field speed, at which the implement Draft requirement and the tractor pull are close to each other for the system to be operated effectively. This required field speed gives the optimum performance for the tractor-implement system. However, the simulation program developed in this study alerts the user to reselect the tractor-implement combination if it will converge in an impractical field speed. The types of alert messages are shown in Fig. 3 and Fig. 4. This ensures that inexperienced users are not misled and the recommended field speed in ASABE [6] is adhered to in the program.

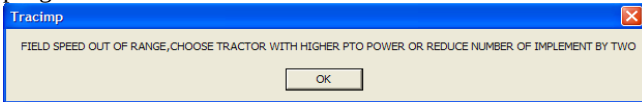


Fig. 3. Alert Message flag to select tractor of higher power rating

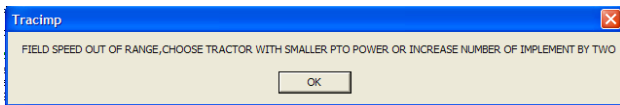


Fig. 4. Alert Message flag to select tractor of smaller power rating

Tractor and implement performance parameters such as field speed, drawbar pull, drawbar power, total implement Draft, field capacity, and actual operating hours are predicted for the selected tractor-implement system. The output window which displays these parameters is shown in Fig. 5.

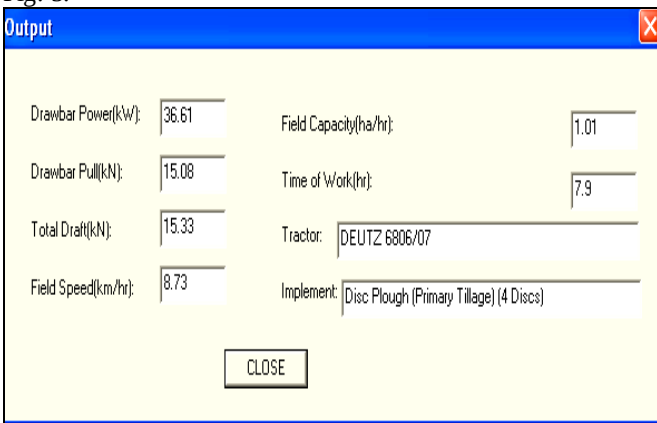


Fig. 5. Output Window for Tractor-Implement System Performance Parameters

IV. CONCLUSIONS

A Visual C++ programs that can be used predict tractor-implement system performance was developed for use in farm machinery management and educational and research purposes. The simulation program finds the optimum practical field speeds for a given tractor and implements combination and predicts the tractor-implement system performance parameters. The visual programming environment used to develop the program makes it relatively

flexible and easy to learn and operated compared to programs developed in traditional languages. It is user-friendly and could be run on any Windows desktop with or without Visual C++ environment. The event-driven visual components in the program allows the databases of the tractors and implements to be edited, updated and manipulated to suit the required task of the user.

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