Interpretation of Technical Illustrations for Airplane Maintenance and Operations Applications

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Modern commercial and military aircraft require extensive maintenance and operations documentation. Traditionally, this has been in the form of multiple paper (or microfiche) manuals encompassing millions of pages including hundreds of thousands of technical illustrations. Much of the critical information that the technician needs to perform his or her task is exclusively located in the illustrations, so that the majority of time spent with the manuals is devoted to accessing and studying illustrations.

The Boeing Company is providing ever increasing amounts of this documentation in electronic form in a family of digital data products. The requirement for users to be able to interact intelligently with the illustrations is evident. In particular, users need a system that:

- provides hyperlinks within illustrations so that users can navigate from graphic to graphic and from graphic to text
- aids users in understanding complex schematics such as wiring diagrams
- provides full text search capability across all text and graphics
- understands the semantics of flow charts and decision trees to assist users in completing complex tasks

Tools exist for manually authoring such capabilities into graphics, but the size of our graphic databases prohibit this approach. We have millions of legacy drawings and any method requiring manual insertion of intelligence is too expensive and error-prone. For example, a single wiring diagram requires hundreds of hotspots with complex geometry and behavior in order to be sufficiently useful as an online aid. Consequently, our research involves the invention of software that automatically analyses the layout of technical illustrations, infers their semantics, and converts them into "intelligent graphics" that allow users to interact with them intelligently [1].

1. Automated Understanding Of Wiring Diagrams.

Our software automatically converts legacy wiring diagrams into interactive graphics that aid the trouble shooting of electrical problems in a number of ways:

- When the technician points at a wire with the mouse cursor, the electrical continuity of the circuit through that wire automatically highlights.
- The user can click on an electrical component, such as a switch or circuit breaker, to interactively change its state and immediately see how that changes the electrical continuity.

- The system provides full text search of the diagrams, making it much faster for the technician to locate the area of interest in the drawing.
- The user can click on nomenclature to query equipment databases for fast access to part information, vendor information, etc.
- The user can link from the database query screen to other diagrams and the system will automatically highlight and zoom in on the equipment of interest.
- The user can click on references to other diagrams to quickly continue following a circuit from diagram to diagram.

This technology enables applications to dramatically improve the usefulness of technical illustrations to end users.

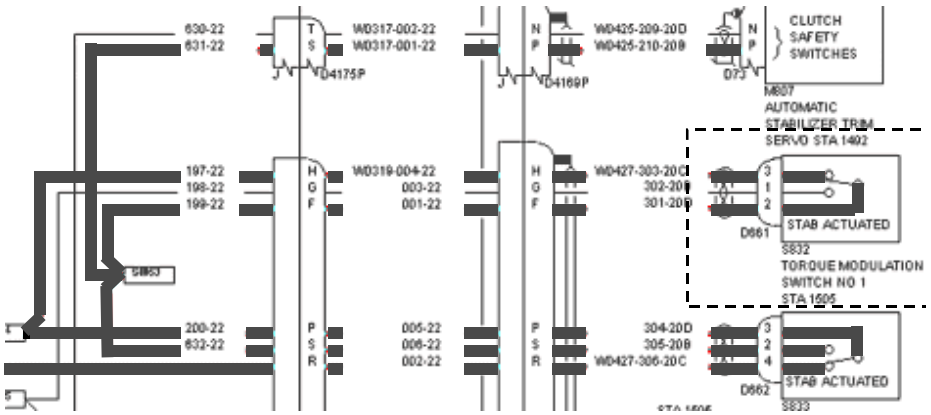

Figure 1: Our graphic recognition enables the intelligent graphic viewer to display electrical continuity.

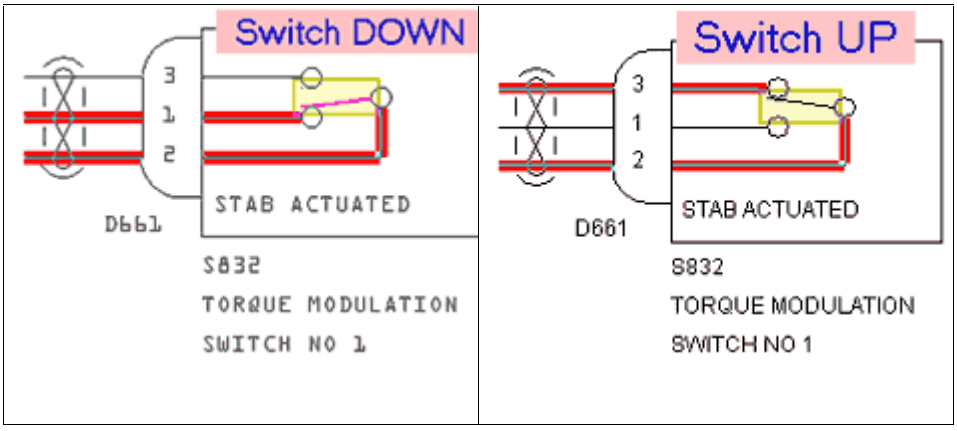

Figure 2: After clicking on the switch to change its state, the circuit flows from pin 2 to pin 3, instead of to pin 1

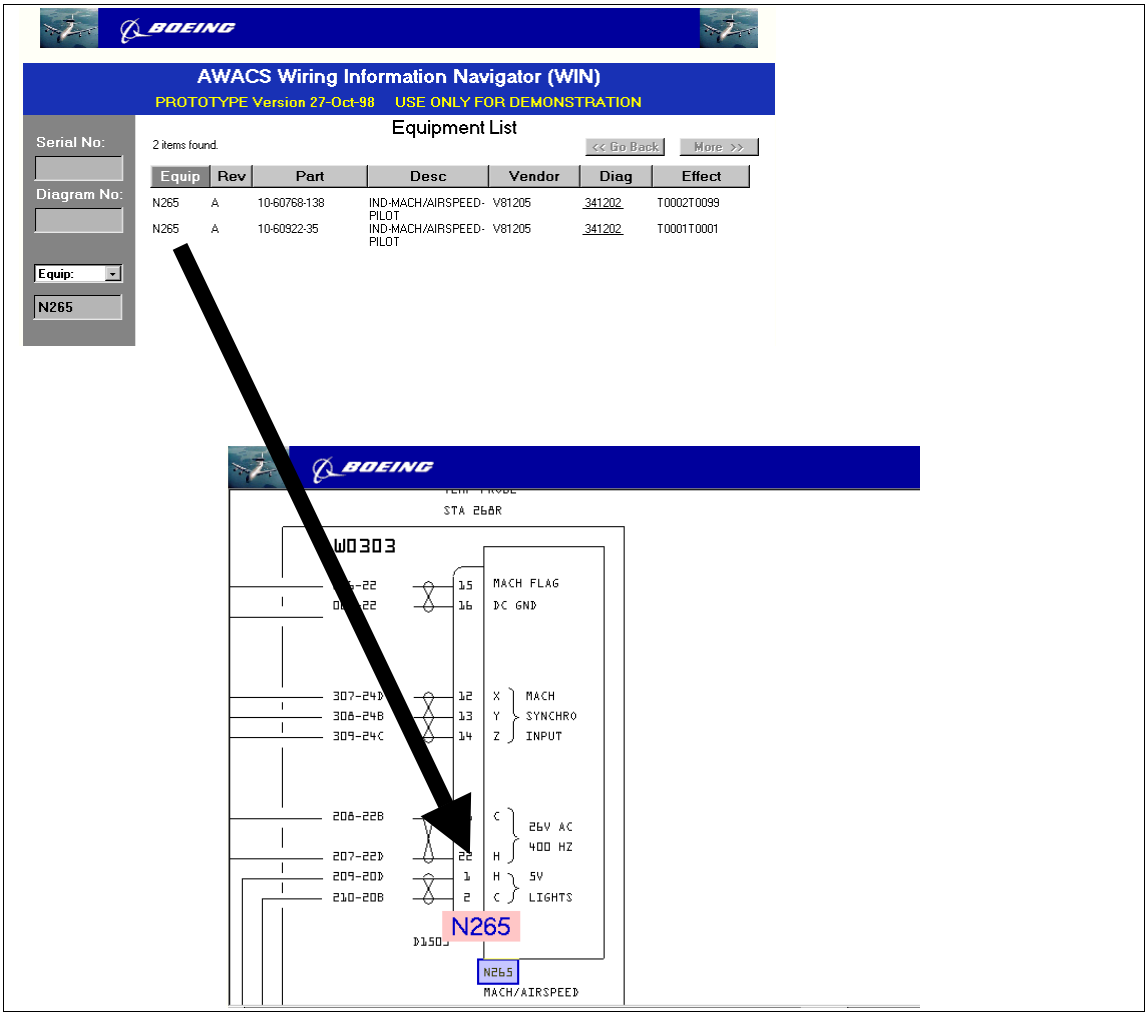

Figure 3: From the database query screen, the user immediately finds the desired component in the diagram.

2. Automated Recognition Enhances Quality Assurance

Airplane maintenance documentation contains many thousands of technical illustrations with hundreds of thousands of references to other illustrations, to text or to equipment databases. Illustrators work diligently to avoid errors in those references, but some errors are inevitable. An important benefit of our approach is that now we can automatically discover errors in the illustrations that otherwise would have required time-consuming (an less than 100% reliable) manual inspection. A number of the tools reported in [1] are now in production and have analyzed millions of illustrations. The software reports errors in trouble shooting procedures, broken hyperlinks, and other problems. As a result, Boeing is achieving significant improvements in the quality of the technical information its customers receive.

For example, there are wiring databases that specify which pieces of equipment (wires, wire bundles, connectors, etc.) are supposed to be depicted on which diagrams. Over time, many diagrams have been significantly edited and discrepancies have crept into the database. Our wiring diagram recognizer produces discrepancy reports so that these errors can finally be detected and eliminated.

The Fault Isolation Manual provides another example. This manual contains many illustrations depicting trouble shooting flow charts, with diagnostic questions in blocks linked together via arrows with YES or NO answers to the questions. Our software analyses the illustrations, infers the flow chart logic and reports on errors such as:

- Missing arrows
- Ambiguities in the flow (two NO paths without a YES path
- Block-to-block links that will not work
- Dead-end paths
- Blocks that cannot be reached
- Cycles in the flow logic

Future Research

While we have had success with recognizing the text in raster illustrations for parts catalogs [1], the majority of our work to date has been focused on vector illustrations. Our future research will more heavily focus on raster diagrams, including structural and tooling drawings. Boeing has millions of these drawings and incurs tremendous cost in the de-design of existing parts because it is too difficult to find existing parts. Automated tools to catalog and search through the document databases could significantly reduce those costs.

Our wiring diagram methodology works for vector diagrams, but there are hundreds of thousands of legacy illustrations in raster. If we had reliable raster-to-vector conversion software, we could convert those diagrams to intelligent wiring diagrams as well, enabling Boeing to provide maintenance aids for older aircraft as well. Such raster-to-vector conversion software must reliably find lines, circles, and circular arcs, and correctly perform optical character recognition on all the text in the diagram. The input would be very clean raster images with machine-printed characters.

References:

[1] Baum, L.S., Boose, J.H., Kelley, R.J., "Graphics Recognition for a Large-Scale Airplane Information System," Graphics Recognition: Algorithms and Systems, Lecture Notes in Computer Science 1389, Springer 1998