J. Edward Colgate, PhD

Michael Peshkin, PhD

Dept. of Mechanical Engineering,
Northwestern University

Founders of Cobotics, Inc.

Intelligent Assist Devices

Revolutionary Technology for Material Handling

cobotics

Intelligent Assist Devices:

The New Standard in Material Handling Technology

This white paper introduces a new generation of computer-controlled devices that is poised to revolutionize material handling operations across the industrial landscape. Intelligent Assist Devices (IADs) enable a unique collaboration of humans and machines to bring unprecedented levels of productivity, quality, and ergonomic safety to manual operations. Using sophisticated sensors, controls, and proven servo motor technology, IADs allow operators to manipulate and position loads with remarkable speed, precision, and ease.

Conventional ergonomic assist equipment is actuated by pressing buttons to control either pneumatic or fixed-speed electric devices. Although these traditional devices have a positive impact on ergonomic safety, they have not been associated with productivity improvements. For applications requiring rapid and accurate movement, they are awkward, slow, and do not take advantage of the natural human ability to coordinate and control motion. In practice, over-travel, bounce, and multiple corrective movements add to cycle time and reduce productivity. The lack of intuitive and responsive control also results in product damage and cumulative trauma injuries. The latter occurs when people force the equipment, or when the frustration of working with unresponsive equipment leads them to put it aside.

In response to these problems, a small group of engineers from the auto industry and academia (including the authors) invented IADs in the mid-1990s. The initial idea was straightforward: use computer-enabled motion control technology to enhance human capabilities. Today, IADs assist their human partners in a wide variety of ways, including power assist, motion guidance, line-tracking, and semi-automation. These features and a number of others will be described in this article. In addition to describing the ways in which IADs can add value to material handling processes, we will also discuss the underlying technology and safety of IADs, as well as the implications for systems integration.

An IAD may have only a single axis, several that work independently, or several that work in coordinated motion. IADs may be classified by their axes of motion (see Figure 1). The axes are denoted X and Y (lateral motions), Z (vertical), roll, pitch, and yaw.

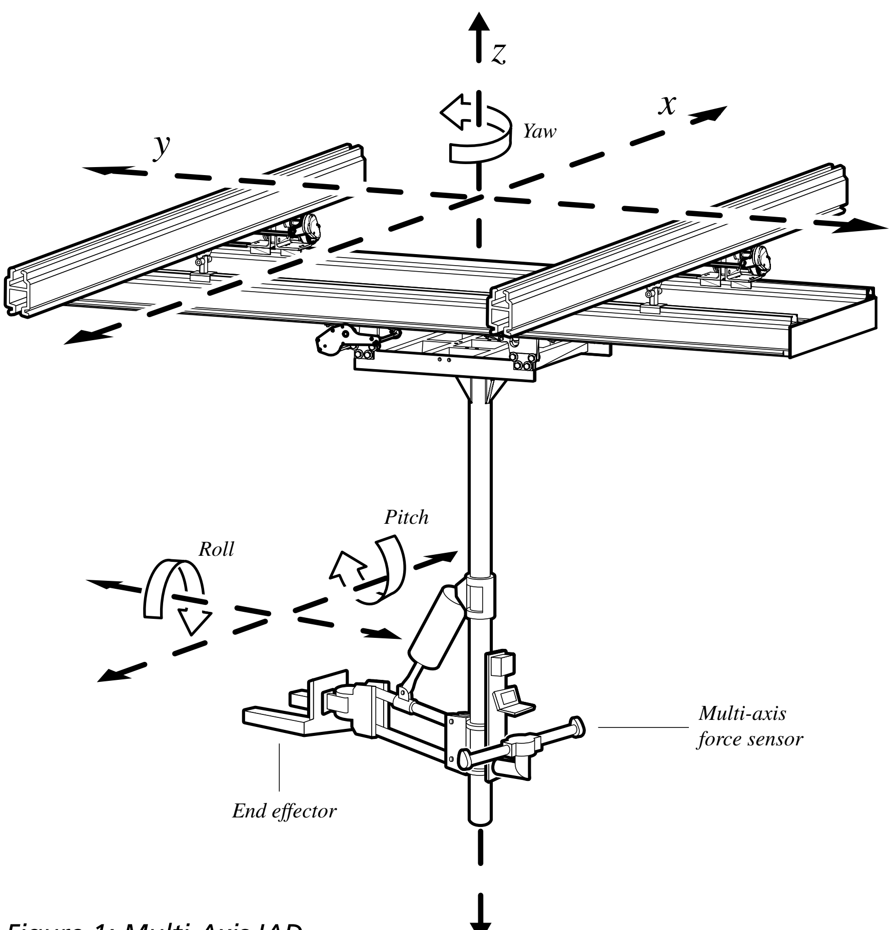

Figure 1: Multi-Axis IAD

Z-Axis Lift

An example of a single-axis IAD is the Z-axis electric lifting and balancing unit (see Figure 2). Z-lifts offer a number of key advances over air balancers and hoists, including improved speed, more intuitive control, greater precision, and the ability to program semi-autonomous behaviors.

Two kinds of controls may be offered with Z-lifts: an in-line force sensing handle and a pendant grip. Both devices allow extremely fine control of up/down speed, regardless of payload weight. Proportional control allows smooth and efficient motion, eliminating the need for feathering (rapidly cycling a control button to achieve small motions) that is common to pneumatic and single-speed electric systems.

Some Z-lifts offer another control mode known as “float” or “hands-on-payload” mode, in which no handle or grip is needed. Float mode is an advance over the “balance” operation of some pneumatic lifts, offering two key advantages. First, the device automatically “learns” the payload weight, so it can balance any load up to its rated capacity, not just one or two preset weights. A second advantage is that the Z-lift is able to detect and respond to very small operator forces exerted up or down on the payload. As such, the Z-lift requires less operator force and responds without the noticeable delay found with pneumatic balancers. Equally important, Z-lifts allow precise positioning by eliminating impacts caused by the bounce in pneumatic balancers, and the single speed of traditional electric devices.

Some Z-lifts are also programmable. Basic features include up/down motion limits, a gripper interlock, and user profiles that set the sensitivity and speed for individual operators. Some Z-lifts offer a built-in PLC-type logic function that system integrators can use to solve task-specific control issues. Examples include auxiliary clamp buttons, remote emergency stop, solenoid actuation on the end effector, and proximity sensors interlocked with clamping functions.

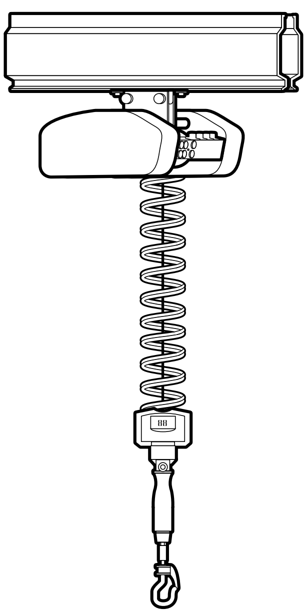

Figure 2: Z-Lift with in-line handle

Intelligent Rail System

While a Z-lift is a good illustration of the functionality that can be packed into a single-axis IAD, an Intelligent Rail System provides an illustration of how multiple axes can work together (see Figure 3).

Intelligent Rail systems address problems associated with traditional overhead cranes and lift assists. While traditional devices can minimize lower back injuries due to lifting, they can cause injuries to the shoulder, arm, and back. Such injuries occur because of the pushing, pulling and twisting forces required to start, stop and redirect the mass of traditional overhead cranes. Additionally, the time required to accelerate and decelerate the overhead mass increases cycle times, especially when precise positioning is required.

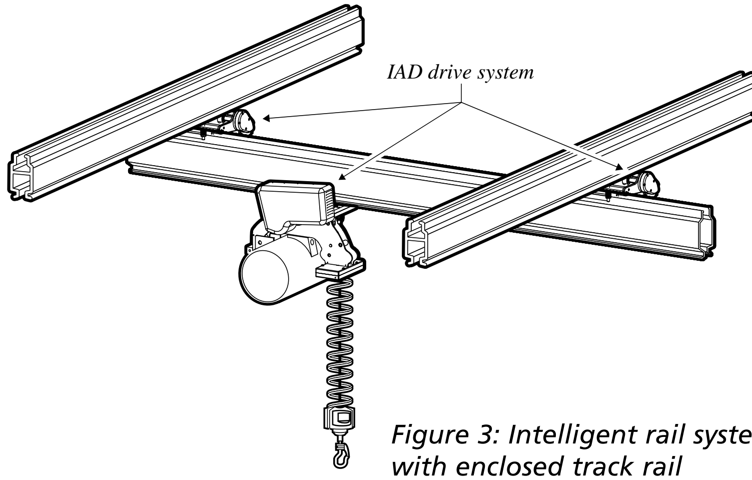

Figure 3: Intelligent rail system with enclosed track rail

An Intelligent Rail System uses servo-controlled trolleys to power the motion of the overhead crane, so that the operator need only indicate the direction he wishes to move, and the system provides the force to accelerate and decelerate the crane. Either one or two axes can be powered, according to need.

In the case of a cable-suspended load, a sensor detects deviations of the cable from the vertical position and uses this information to control the trolleys. There are no pushbuttons; the IAD moves in response to the operator pushing on the payload. The net effect is that the mass of the overhead structure is masked, eliminating inertia and momentum. The system tracks the operator’s motion, allowing him or her to focus on the positioning task. Not only is starting and stopping much easier for the operator, but, in a two-axis system, it is just as easy to move the load in one direction as another. This is in sharp contrast to conventional bridge crane rail systems where it is more difficult to move the bridge itself than move along the bridge.

In the case of a rigid system such as a manipulator arm, a multi-axis force sensor is used to detect operator intent and apply this information to control the drive units (see Figure 1). The net effect is that the mass of the entire load (including the overhead structure, the manipulator arm, and the payload) is masked from the operator, eliminating the deleterious effects of inertia and momentum. Like the Z-lift, Intelligent Rail Systems are programmable. Motion limits can be established for each powered axis, user profiles can be set, and advanced PLC-level functions are available.

Multi-Axis IADs, Virtual Surfaces, and Semi-Autonomy

IADs are capable of a much higher level of functionality using what are known as "virtual surfaces." Virtual surfaces are so named because they are defined in software, but their effects are quite real. As illustrated in Figure 4, they can be used to guide operator and payload motion while preventing unwanted impacts. Virtual surfaces can improve productivity and ergonomics as well. By way of analogy, consider the familiar task of drawing a straight line on a piece of paper. While possible to do freehand, the task is done much faster and better with a ruler. Virtual surfaces are like rulers, only multi-dimensional, and most importantly, user-programmable.

An example of a virtual surface application is loading seats in vehicles. As the operator approaches the vehicle, payload motion is guided such that the seats pass through a virtual window aligned with the opening in the side of the vehicle. This feature automatically adjusts the load to the proper height and prevents damage caused by accidental impact with the painted surfaces or interior trim. The system also provides line tracking, or synchronization, in order to keep the virtual window lined up with the moving vehicle.

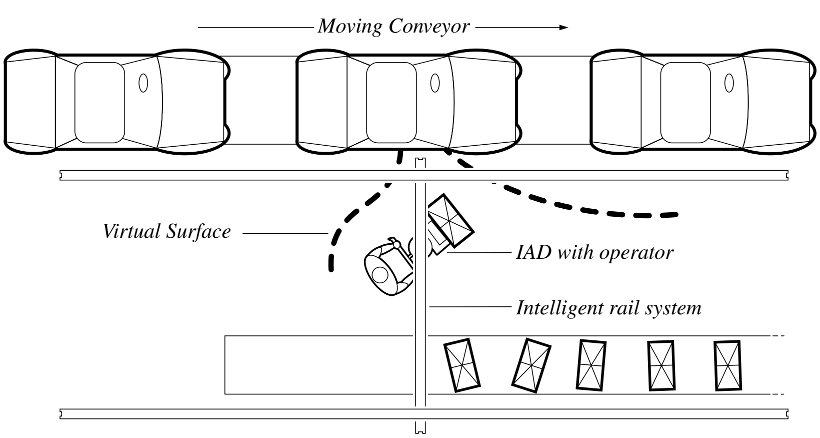

Figure 4: Virtual surfaces illustration

Multi-axis IADs can also be programmed to perform semi-autonomous functions such as returning to a home or loading position, automatically retrieving a new part, or synchronizing with a moving assembly line. Semi-autonomous operations allow the operator to focus on value-added tasks, while the IAD takes over routine movements.

Multi-axis IADs are ideally suited for the assembly of large components such as automobile instrument panels, which require both precise handling and secondary assembly operations such as inserting fasteners and connecting wire harnesses. While some elements of such tasks would benefit from the precision and speed of automation, other elements (like connecting wire harnesses) require the dexterity and intelligence of human operators.

Other Benefits

Because IADs employ the power of advanced computers, they can provide many ancillary benefits such as:

- **Data logging.** IADs can log process variables such as the number of cycles, average cycle time, average weight lifted, cumulative weight lifted, and total distance traveled.
- **Error-proofing.** IADs can be programmed to assist operators by error-proofing tasks. Examples include weighing a case of standard products and indicating if one is not filled, or prohibiting the movement of a part into the storage area designated for another part.
- **Preventive and predictive maintenance.** IADs have the ability to send email messages to plant maintenance personnel when routine maintenance is required. Additionally, they can notify personnel in the event of fault conditions.

Advantages of IADs

Productivity

- Power-assist and intuitive proportional controls allow operators to work quickly.
- Virtual surfaces guide payload motion, for smooth and efficient operation.
- "Semi-autonomous" behaviors such as "return-to-home" let operators focus on high value-added tasks.
- These characteristics and behaviors collectively allow IADs to support precision assembly, such as the modular build of automobiles or delicate operations such as handling ceramic green-ware.

Quality

- Highly intuitive and responsive behavior allows operators to move naturally and minimizes new-operator training times.
- Virtual surfaces protect Class A surfaces and prevent accidental collisions with other objects.
- Interlocks and/or virtual surfaces support operator decision-making and provide error proofing.

Ergonomics

IADs reduce strain on operators arising from:

- Workpart, tooling, and structural inertia.
- Friction of conventional assist devices.
- Awkward postures.

Information Management

- On-board computers allow IADs to log data, such as number of picks, cycle times, etc.
- IADs can interface with plant information systems.
- IADs can alert maintenance personnel (e.g., via automatically generated email messages) to preventive maintenance and fault conditions.

Case Study

The Z-Axis IAD pictured here helped a major automotive supplier to increase productivity by 100% while improving ergonomics.

In the application, assistance was needed to help an operator pick up an unwieldy, 4' x 3', 42-pound catalytic converter from a turntable and carry it to a gage fixture for leak testing. Once the part passed the test, it needed to be moved to a shipping rack.

The required production rate was 100 parts per hour, resulting in 200 lifts per hour.

Initially, an air balancer was used, but it was difficult to control and required long learning curves that caused the operators to abandon this equipment and perform the task manually. This resulted in a bottleneck on the line that reduced productivity, and required an extra operator to keep up with the line speed, which increased costs significantly.

Moreover, the repeated lifting movements caused back discomfort and fatigue, putting operators at risk for ergonomic injuries. In effect, a human operator was responsible for manually lifting up to 62,700 lbs. per 8-hour shift.

The solution was a Z-Axis IAD requiring low force to operate and offering intuitive operation, programmable and automation features, high speed, and precise control.

The IAD enabled a single operator to lift each heavy catalytic converter as if it weighed just ounces, and its fast, smooth movements helped reduce cycle times.

The Z-Axis IAD allowed the company to increase productivity and minimize injury risks while lowering costs dramatically. Furthermore, the IAD was immediately embraced by operators.

Picture courtesy of Visteon Corporation

Underlying Technology

IAD technology owes a debt to various university and government research programs in the areas of remote manipulation and haptics—the use of force-feedback to let a person work with a machine in a natural and intuitive manner. Like those disciplines, IAD technology operates on the basis of:

- Sensing the intent of the human operator;
- Processing that intent through sophisticated control algorithms, running on industrially hardened computers; and
- Causing payload motion based on the controller output.

IADs are commercially viable today in large part because these three steps have become increasingly cost-effective: novel and inexpensive human intent sensors have been developed; the cost of embedded computing has dropped dramatically; and increasing levels of automation have led to more cost-effective servo motors.

Safety

Unlike robots, which move according to their own programmed instructions, IADs respond to real-time, human intent. Like any powered machinery, safety is a paramount concern in design, installation, and operation. IADs are subject to a safety standard created in recognition of the unique coexistence of a human and computer-controlled machine in the same work cell. The ASC T15 Safety Standard for Intelligent Assist Devices, developed by a Robotics Industries Association committee, is expected to become an ANSI standard in the near future. The Standard covers dynamic limits, safety circuits, clarity of communication between operator and IAD, and risk assessment procedures.

System Integration

Unlike automated systems, IADs generally do not require sophisticated sensors such as vision systems, high levels of precision, or expensive tooling. Instead, IADs leverage human perception and intelligence, capabilities that are difficult or expensive to capture with machines. An additional benefit is strong worker acceptance, because IADs help human workers rather than replace them.

IADs, such as Z-Lifts, can work directly "out-of-the-box," with installation similar to that of a conventional hoist or balancer. To fully exploit the programmable features of an IAD, some degree of set-up is required. Basic features, such as setting an interlock weight, can generally be accessed using pushbuttons on the IAD itself. More sophisticated features, such as tuning a user profile or logic programming, can be accomplished with easy-to-use graphical interface programs on a laptop computer.

Physical integration of IADs is quite similar to the integration of conventional assists, although pneumatic supply and logic hoses tend to be replaced by electric power and signal lines. A well-designed IAD will provide power and logic connections for system integrator use, minimizing the need for additional electronic enclosures. Also, a well-designed IAD can be installed on existing enclosed-track rail systems, thereby allowing easy retrofitting and simple, familiar installation.

Conclusion

IADs are powerful tools for productivity, quality and safety. By combining the unmatched human ability to coordinate motion and adapt to changing circumstances, with the strength and precision of industrial machinery, IADs will forever change materials handling.

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2506 Gross Point Road • Evanston, IL 60201 • 847.425.1200 • fax: 847.425.1201 • www.cobotics.com