

THE COMING TSUNAMI: Service Robots

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Background

With the proliferation of embedded microprocessors in the process and automotive industries during the 1980's it was only natural that entrepreneurs would look to this same technology to revolutionize the commercial cleaning industry. The original goal was and continues to be to take a manually operated floor cleaner and turn it into fully autonomous machine (i.e. robot) that can match or exceed the cleaning performance of a human without intervention. This challenge was taken up by a number of industry and educational groups across the globe. With a commercial cleaning market size at the time of over \$40 billion worldwide, dozens of companies and educational groups took up the challenge and began introducing prototypes as early as 1987.

Thirty years later however, with the exception of some robotic vacuum cleaners, robotic cleaning as a whole has failed to reach its potential, particularly with respect to floor scrubbers. This white paper looks specifically at the history and evolution of these machines and identifies the obstacles that have prevented

their wide spread adoption. Today there are a number of companies that are bringing products to market that have broken through the major technical and operational barriers. The time has arrived for commercial businesses, particularly in the retail, industrial/warehouse, education, airport and office building segments to reconsider robotic cleaning.

A 35-year journey... and counting

In August 1983 my motivation to pursue and integrate robotic cleaning equipment into my business was ignited. My three-year-old cleaning company, Commercial Services of Virginia, had a contract to clean a local Sears store. Ten employees were expected to show up at 5 AM to begin the work – not one made it. As I have experienced numerous times throughout my career, assembling and maintaining a reliable work force is one of the greatest challenges in the conventional contract cleaning industry. There are multiple reasons for this.

- Cleaning work is entry level, low wage employment. As a result, high turnover and poor-quality work are constant challenges.
- To make it even harder, most cleaning is done on second and third shifts. This serves to increase the absenteeism, turnover and quality problems.
- Much of the staffing has come from first generation immigrants. Increasingly restrictive immigration policies have made it that much more difficult to fill staffing voids.
- As humans we are ill-constructed to perform boring, repetitive tasks. Cleaning floors ranks high on the list of tasks that fit this profile.

With the recognition that these conditions are characteristic of the industry as a whole, I undertook research to identify robot development companies. Over the next several years, this led to an expanding relationship with Transitions Research Corporation (TRC) led by Joe Engelberger, who became a life-long

friend and my mentor. Joe's enthusiasm for adapting robotic technology to floor cleaning proved instrumental in raising over \$10 million in funding from Electrolux to assist TRC in the development. The first model was launched in 1987 under the RoboKent brand.

1st generation machines hit the market

Over the next decade, a number of companies emerged as industry pioneers. They included:

- RoboKent/Kent
- Cyberworks
- Midi Robotics
- Robosoft
- Hefter
- Cyberclean Systems
- Von Shrader
- Fuji
- Toshiba
- Hako
- Cybernetix
- Karcher
- Intellibot

Robots developed during this time covered applications for sweeping, vacuuming, floor scrubbing, courier services and guard security. As the industry entered the 21st century, however commercial success was missing altogether. Why was this the case? Putting the issue of cost aside, inadequate performance was the main reason. The principal performance challenges that these first-generation products encountered included:

- **Accurate navigation** – Seeing and interpreting the working environment proved much harder in the field than in the lab. The popular and predominant sensor of choice at this time, ultrasonics, while cost effective, had significant limitations. Moreover, consistently and accurately navigating the prescribed cleaning area proved unreliable as floor scrubbers depended on calculations tied to the rotation of the wheels. Wet floors would result in wheel slippage, which led directly to errors in distance calculations and robots that failed to clean the entirety of the programmed surfaces. Worse yet, if the error was significant, the robot would get lost and would be unable to re-establish the correct route.
- **Obstacle avoidance** – as is the nature of the cleaning challenge, on any given day a wide variety of “obstacles” can appear in the path of the robot that were not there at the time when the robot was initially programmed. Knowing how to avoid (running into) obstacles and navigating around them proved to be a challenge that this first generation of robots failed to master.
- **Facility mapping** – the Graphical User Interface (GUI) methodology for inputting the desired cleaning route into the robot proved to be something that required the aptitude of an engineer, not that of a typical operator in the cleaning industry. This negatively impacted acceptance by the very companies the suppliers were trying to attract.

- **Operator Training** – as might be expected with any high-tech, first generation solution, the learning curve associated with these robots was steep, and the offerings were definitely not ready for main stream adoption. Marketing into an environment where the contractors put together bids based on the quantity of personnel assigned to a facility, any specialized labor or additional support costs only pushed the contractor into an uncompetitive position in what is already a low margin industry.

Behind these operational challenges was technology that wasn't ready to meet the demands at an affordable price point. Below is a list of the primary deficiencies that the industry faced.

- **Processing power** – the generation of microprocessors that were available to these pioneering companies lacked the speed, memory and I/O that was needed to solve all of the above-mentioned performance issues.
- **Self-learning software** – artificial intelligence (AI) and more broadly machine learning was still in its infancy during the 1990's and in fact it is only in recent years that the availability and the proven application of this technology has become widely available and affordable.
- **Sensing Technology** – sensing of the environment drew upon ultrasonics, infrared and touch sensors in order to navigate the cleaning route and to understand when an unknown object was encountered. Ultrasonics struggled with even minimal route complexity including wide aiseways and infrared sensors didn't recognize glass walls. Lasers proved to be too expensive, and high definition video didn't exist. As a result, performance shortcomings in navigation and obstacle avoidance remained an issue until only recently.

- **Wheel Slippage** – this problem has ultimately been solved through improvements to drive motors and the addition of self-correcting software algorithms, but it was definitely an issue with this first generation of robots.

The 21st century dawned, progress remained slow

As the industry entered the 21st century, I remained convinced of the viability of robotic cleaning, which ultimately led me to selling my conventional contract cleaning business. Using the proceeds from the sale, we purchased the assets of RoboKent from Nilfisk Corporation and began manufacturing and selling robots in our new company and under a new brand, Intellibot. During the next four years we raised an additional \$7 million in development funds but much to our disappointment became painfully aware that this level of investment was grossly inadequate. The business was ultimately sold to Henry Hillman of Axxon Robotics in 2003 and today the Intellibot robot lives on under the direction of Diversey. The lesson that I learned is one that has been repeated by many others in the industry - perfecting a commercial-quality cleaning robot requires substantial financial and technical resources. To this point, Intellibot was sold in 2015 to Sealed Air and again as part of the Diversey sale in 2017 to Bain Capital, both of whom have the financial wherewithal to support the significant investment required and stay the course. In addition, Brain Corporation, San Diego, CA, received \$114M in Series C funding from SoftBank and Qualcomm Ventures in 2017 in order to fund development of its BrainOS platform. This promising and impressive software platform is designed to create autonomous commercial service robots using off-the-shelf hardware and sensors.

During the first 15 years of this century, progress in robotic cleaning has been largely evolutionary, with industry suppliers taking advantage of continuous advancements in computer processing, software development and sensing

technology, particularly video processing and lidar. Unfortunately, the results from a commercial perspective during this period have been largely disappointing with volume shipments conspicuously absent, with the exception of residential vacuum cleaners such as the Roomba by iRobot. There is no question however, everything is about to change in the commercial market.

The industry has reached its tipping point

It appears that the “perfect storm” has arrived upon the industry’s shore. Across the board advancements in the fundamental technologies and the requisite investment in their development are resulting in new offerings that are fully addressing the performance and operational requirements identified over two decades ago. Evidence of this “rebirth” as well as validating a burgeoning market is the annual attendance of companies selling cleaning robots at the ISSA (International Sanitary Supply Association) show. For more than a decade up to 2015, there was a single company represented. This year at the ISSA 2018 show, the number will be close to 20 firms from all parts of the globe, and with the exception of Intellibot, all of these companies are relatively new entrants to the market.

Promising technology advancements are also well underway which will serve to further enhance and expedite product development and market acceptance. ROS (Robot Operating System) is an open source software framework growing in popularity which enables developers to build products faster and more easily on a common platform. New promising algorithms such as SLAM (Simultaneous Localization and Mapping) while not there yet is close and will enable robots to deal with a forever changing environment on the fly without reprogramming. 2D and 3D Kinect sensors, proven and currently used in the game industry (e.g. Microsoft’s Xbox), significantly enhance robot perception yet cost only several hundred dollars. And much more.

With the adoption of robotics comes a reduction in labor, a shift to capital investment and most significantly a fundamental shift in thinking on the part of the industry. As a highly competitive industry, robotic alternatives must be equal to or less in cost to operate. Further, since much of the industry is served by independent contractors, building owners and property management firms must be convinced that robotic cleaning is reliable, meets their performance standards, and cost effective. As buyers, if you specify robotics, the contracting community will respond even if they are initially reluctant to do so.

Case studies from this latest generation of robotic cleaners are demonstrating that both the performance and cost criteria are being met. As a result, I have reactivated Cyberclean Systems as a robotics-based service provider and industry consultant based in Richmond, Virginia initially integrating robots from Intellibot and Brain Corporation. Knowing that there is a coming product and technology tsunami, we are purposely technology agnostic and will continue to assess, evaluate and ultimately use and / or recommend the best robot technology wherever it may come from. It's been a long road to success, but my enthusiasm for this industry has never been greater. I strongly encourage facility owners, facility managers, facility service providers and building service contractors to take a very hard and serious look at this exciting paradigm shift now well underway.

There's so much more coming

Our vision is well beyond just floor cleaning and is just as real. There are many robotic solutions that are emerging across a wide range of applications within and outside of buildings, all falling under the heading of facilities services. ABM Industries pioneered and has long ago proven the value of fully integrated facility services to its customers. Offering a full menu of services including janitorial, security, landscaping, window washing, mail/courier services, maintenance, parking garage/lot maintenance and other services as a bundled contract has

provided a seamless, cost effective and efficient process for facility owners and managers to manage traditional facility services. Along these lines, there are exciting robot developments pertinent to all of these facility services and one day, I am convinced in the not too distant future, will be offered as an integrated robotic services package to facility owners and managers.

As examples of other facility service tasks currently being robotized, consider the following. Window washing for office towers is both dangerous and expensive. Fraunhofer Corporation from Germany and Pufeng Intelligent Technology Co. from China are both developing window washing robots to address this challenge. Fraunhofer has also developed a mobile robot that has an arm to pick up trash from a receptacle and can, at the same time, vacuum small offices throughout a building- repetitive, monotonous daily tasks that consume large amounts of man hours in a building. Cyberworks of Orillia, Canada, has impressive technology integrated into rider vacuums and scrubbers and performing advanced precision navigation not seen before. Discovery Robotics, Pittsburgh, PA, has an exciting and novel approach using beacons, lithium batteries enabling 8 hours of continuous run time as well as interchangeable cleaning subsystems. In the area of security, take a look at the robots from Knightscope of California and Robot Security Systems of the Netherlands – guards that work around the clock! For a more human touch, guests staying at the Mandarin Hotel in Las Vegas, are greeted by “I’m Pepper” who never tires to answer their questions. Material handling in manufacturing has proven an excellent testimonial. Just look at Kiva Systems, acquired by Amazon in 2012, now with more than 30,000 installed robots, or Clearpath Robotics (Kitchener, Ontario) and Otto, its exciting new robot for material handling services. Courier service robots manufactured and distributed by companies such as Swisslog, a division of the Kuka Group, Aethon (Pittsburgh, PA) and Savioke (San Jose, California) are all terrific and exciting examples of courier robots that have proven their mettle. Facilities will even be able to cut their grass with robots – take a look at the solution coming from Belrobotics of Belgium. And finally, the robotics

company with the most watched YouTube videos is clearly Boston Dynamics of Waltham, Massachusetts, where you can watch Spotmini, Atlas, Handle, Spot, LS3, Wildcat, BigDog, Sandflea and Rhex in action. We are now on an explosive technology trajectory in our industry. There is no turning back. It is very exciting to see it finally happening.

Implicit however in this major paradigm shift is the loss of traditional jobs. This happens with all major technological change. However, new and exciting jobs which never existed before, require new skillsets and command higher pay will be created to replace many of the older ones. Extensive programs for retraining existing workforce will be critically important and the foundation for successful change. Robot operators, Cybertechs as we call them, who control and monitor multiple robots onsite or remotely, will be new, exciting and significantly higher paying jobs. Technicians who install and support robots will also be a huge need resulting in a new skillset and new jobs which will replace the old. Workforce training and retraining will be a vitally important and necessary part of the equation for crossing the chasm and long-term success.

To me, all of this clearly validates there is a huge and exciting market. Robots are either available or being developed now for each of these critical areas of facility services. Ultimately offering a diverse and fully autonomous robot system all in a seamless, integrated package is the holy grail and will, without question, bring enormous value to the end user including quality enhancements, process efficiencies, and improved profit margins to those facility owners, managers and service providers who embrace these inevitable changes.

About Buck Ward



Buck Ward is Founder and CEO of Cyberclean Systems of Richmond, Virginia. Cyberclean serves as both a service provider and robot technology consultant to the Facility Services industry. Buck's engagement with cleaning robots began in 1983 with an idea to solve his staffing needs using robots. For more than 3 decades and across many different robot projects Buck has been privileged to work with the very best technical and operational teams anyone could have

worked with and to each of them Buck gives most of the credit for the success he has had. Between 1985-1987 Buck was an industry consultant to Transitions Research Corporation, the company that developed the navigation and control electronics for the original Electrolux (RoboKent) scrubber machine. Between 1989-1992 Buck and his team worked with Cyberworks, Orillia Canada, in a joint project to further develop the Cybervac robot and also served the company as its chief sales and marketing arm. Between 1996-1998, Buck and his team licensed technology from Cybermotion, Roanoke VA, and developed a prototype of the very first fully autonomous vacuum robot incorporating an autonomous docking station and relays to enable the robot to move from floor to floor calling elevators. Buck ran a commercial cleaning business from 1980 through 1999 in which he deployed cleaning robots from Kent, Cyberworks and Cyberclean Systems primarily in hospitals, schools, big box retail, and office buildings. In 1999, Buck sold his cleaning business to Associated Building Services (later acquired by GCA Services) and used the proceeds to purchase all of the assets including the intellectual property of RoboKent moving the company from Elkhart Indiana to Richmond Virginia where it remains today. At the time of the purchase, RoboKent, a division of Kent Company and together part of the larger Electrolux commercial family, had just been acquired by Nilfisk of Denmark. The new company was renamed Intellibot and operated under Buck's direction until 2003,

at which time it was sold to Henry Hillman of Axxon Robotics. Buck worked as part of Henry's management team until 2007. Since this time, Buck has continued as a consultant to the industry and engaged in projects and business startups ranging from the feasibility and design of cleanroom robots, to the conceptual design of a control and navigation module ("black box") embedded into traditional cleaning machines, to the conceptual design of a complete, multi-tasking robot system performing all the daily floor cleaning tasks required in big box retailers. And others.

Buck remains, as he has been for 35 years, a true believer and robot evangelist. Buck can be reached at bward@cybercleansystems.biz