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Measuring Biomechanical Stresses in Machine and Live Scrumming Using CompactRIO and LabVIEW



NI Scrum Machine

"The combination of LabVIEW Real-Time and CompactRIO proved ideal for this application because it offered deterministic triggering control across multiple devices simulating both training and real match conditions."

- Dario Cazzola, [University of Bath, Sport, Health & Exercise Science Department for Health](#)

The Challenge:

Studying the risk factors and physical demands of scrummaging to prevent injury and improve athletic performance in rugby.

The Solution:

Using the NI CompactRIO platform, NI LabVIEW software, and the latest in scrum machine technology to acquire accurate synchronised measurements during live scrummaging.

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In Rugby Union, the scrum is a fundamental phase of the game that aims to restart play quickly, safely and fairly after a minor infringement or stoppage. Comparable to tug-of-war, it involves eight players from each team locking heads and shoulders, then pushing against each other to gain ground and possession of the ball. Between 6 to 8% of rugby injuries are sustained in scrums - however, this figure is skewed by the minor injuries inherent to the sport. Of all the catastrophic spinal injuries that occur in rugby, which often have life changing consequences, 40% are attributed to the scrum.

The International Rugby Board (IRB) identified the need for a thorough understanding of the risk factors and physical demands of scrummaging, with a focus on injury prevention and improved athletic performance.

The IRB selected the Rugby Science Group at Bath University to investigate scrum mechanics and determine the causes of the injuries suffered throughout the sport. The IRB agreed to fund the research, which was conducted through two phases. Phase 1 focused on gathering data from real rugby teams scrummaging against scrum machines during live training sessions, while Phase 2 involved data collection during team versus team scrummaging.

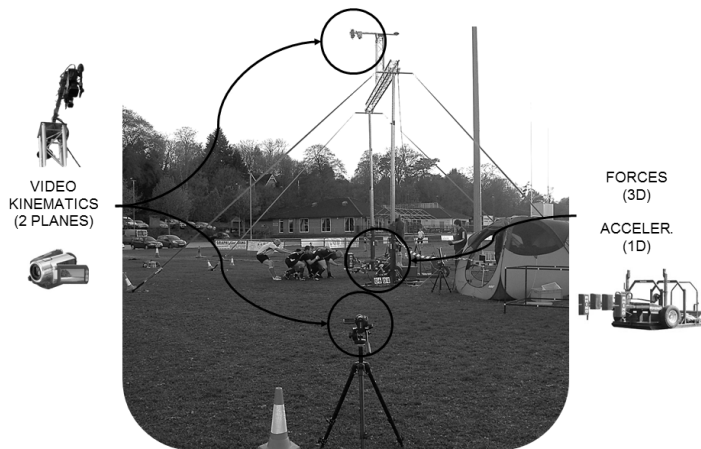


Figure 1. Measurement System Used During Phase 1

Phase 1

The main system comprised a scrum machine fitted with an NI cRIO-9024 controller. Scrum machines feature weighty padded frames, often mounted on wheels, which act as a safe environment to practice scrummaging techniques and build strength. The robust and hot-swappable CompactRIO modules provided the instrumentation for making measurements; the cRIO-9024 acted as an intelligent data logger.

We fitted the scrum machine with strain gages and accelerometers to measure forces at play. These measurements are synchronised with video captured from multiple cameras to analyse the player's technique side-by-side with the force data. We also mounted a loudspeaker on board the scrum machine so the CompactRIO system could mimic the referee by playing sound files containing shouts of crouch, touch, pause, and engage to start the scrum.

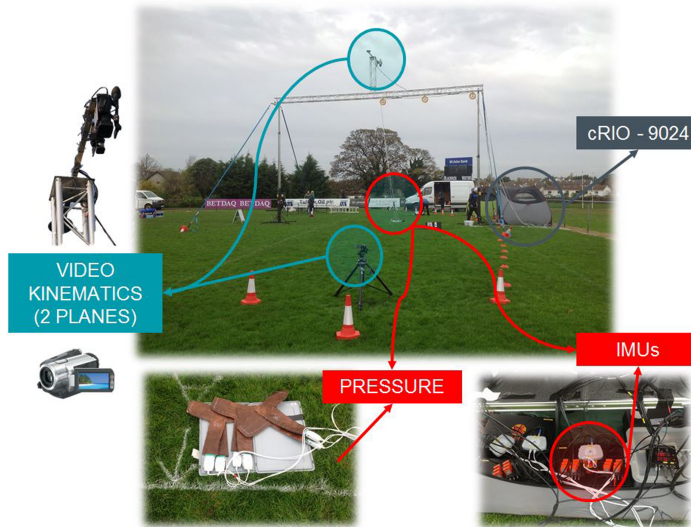


Figure 2. Measurement System Used During Phase 2

Phase 2

The measurement system integrated three subsystems (Figure 3):

- A sensor (F-Scan from Tekscan, Inc.) that measured pressure exerted between front-row players
- Inertial measurement units (MTw from Xsens Technology) that measured the accelerations experienced on the trunk and forehead anatomical segments of each front-row player
- Four video cameras (two side cameras and one top camera at 50 Hz, and one top camera at 200 Hz) to capture player movement

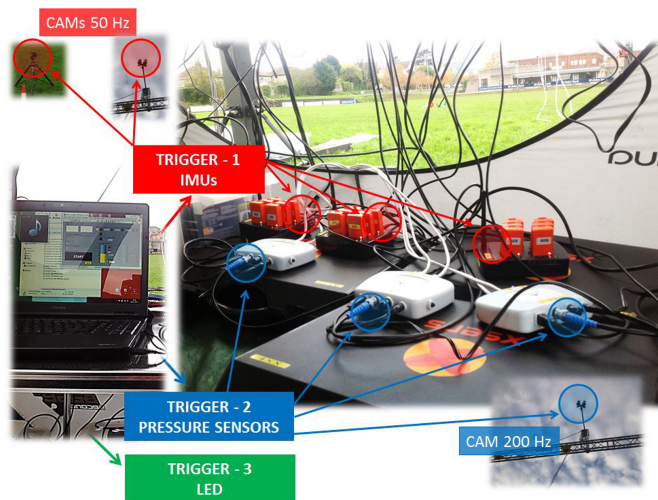


Figure 3. Triggers produced by the CompactRIO are used to correlate a variety of measurements

A real-time cRIO-9024 controller synchronised the measuring devices, and was tightly integrated with specifically designed NI LabVIEW software. We used a prerecorded audio sequence simulating two different referees' calls as a timeline for the synchronisation. The recording played on a loudspeaker to ensure consistency for all teams during experimental trials. The CompactRIO modules sent triggers (Figure 3) to the measurement devices at appropriate times within the audio sequence to ensure collection of the relevant data (Figure 4).

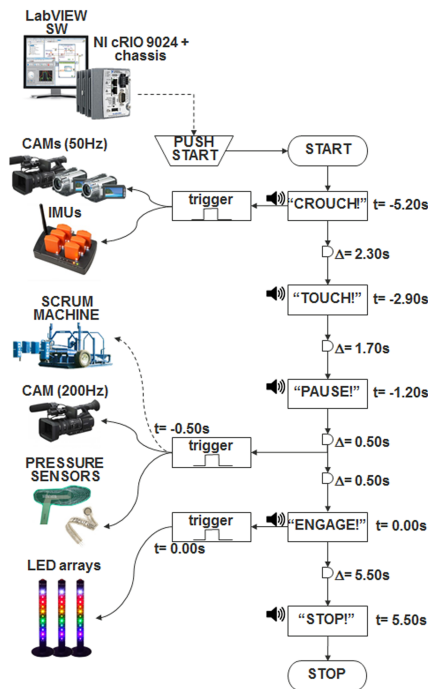


Figure 4. Triggering the referee audio commands

Lastly, the CompactRIO triggered LED arrays visible in each camera view at the instant of the engage or set referee commands for subsequent time synchronisation of video data and force data to within 1 ms.

Phase 1 of the research represented our team's first real use of LabVIEW integrated with NI hardware, so we opted to attend formal training courses and certification exams provided by National Instruments (LabVIEW Core 1, Core 2, Real-Time and FPGA), and achieved the subsequent certifications. These practical, instructor-led courses played a key role in ensuring the success of the project, by dramatically accelerating our proficiency with NI tools. Starting from the "Phase 1" experience, the research team developed "Phase 2" using a similar architecture, integrating different triggers and optimising algorithm determinism (1ms time resolution).

Revolutionary Results

The results from Phase 1 and Phase 2 testing revolutionised the data available and have provided the rugby community with objective biomechanical data regarding the physical stresses acting on rugby forward players, both during machine scrummaging and live scrummaging.

The data gathered during Phase 1 of testing with the CompactRIO system found the magnitude peak compression forces created during scrums were twice what was recorded in the past (16.5 kN versus 8.0 kN for international players). The Rugby Science Group at University of Bath conducted tests using the latest in scrum machine technology in real training sessions on real rugby pitches. The NI CompactRIO accurately controlled both signal triggering and force data logging for a consistent comparison of synchronised force and kinematic data between different engagement techniques and playing levels (Figure 5).

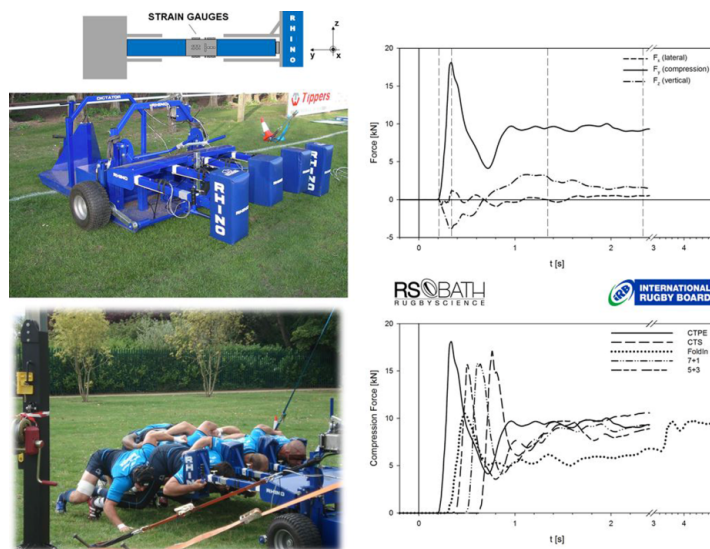


Figure 5. Comparing force and kinematic data between different engagement techniques and skill levels

Phase 2 progressed naturally after Phase 1, and with the small, low-power nature of the CompactRIO system, we could measure realistic data in real-world conditions. With CompactRIO hardware and the [LabVIEW Real-Time Module](#), we controlled and synchronised body-worn sensor technologies, video cameras and LEDs with the utmost determinism and reliability (Figure 6).

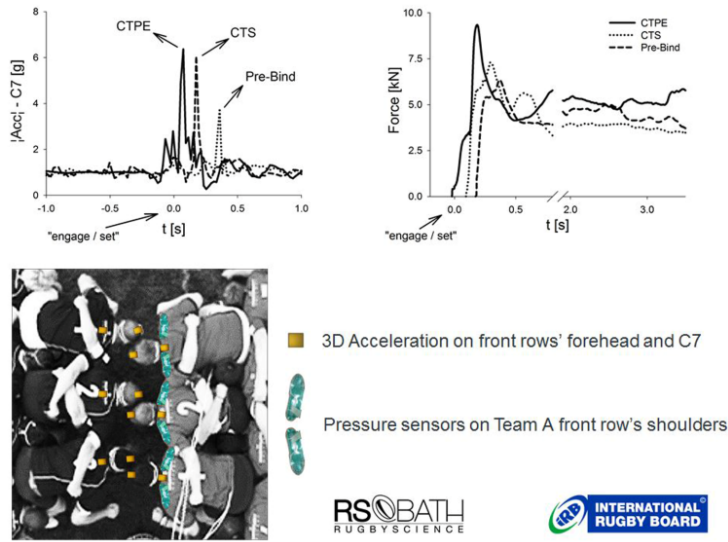


Figure 6. Synchronising data from body-worn sensor technologies, LEDs and video cameras

Improving Safety

The combination of LabVIEW Real-Time and CompactRIO proved ideal for this application because it offered deterministic triggering control across multiple devices simulating both training and real match conditions. The consistent data collection and full analysis of force, acceleration, and movement patterns formed a quantitative basis for any potential coaching or law amendments in the international rugby championship. Another vital approach in improving safety across the sport was broadening the pool of available data. The research team addressed this by measuring the physical stresses and movements relative to rugby players from both genders and six different skill levels—from school teams to international squads.

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